Decomposition of efficiency using DEA window analysis

A comparative evidence from Islamic and conventional banks

Fekri Ali Shawtari, Milad Abdelnabi Salem and Izzeldin Bakhit
Community College of Qatar, Doha, Qatar

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Abstract

Purpose – The purpose of this paper is to examine empirically the efficiency types of Islamic and conventional banks. It seeks to show whether the efficiency level of conventional and Islamic banks significantly differs from each other. In addition, it investigates the influential factors on each type of efficiency.

Design/methodology/approach – The paper utilises the data envelopment analysis in its windows version to estimate the efficiency scores reflecting the time variance and compares between banking models. The paper uses pure technical efficiency (TE) and scale efficiency to achieve the objective of the study. In addition, the panel data technique is adopted to assess the determinants of the efficiency of the banks econometrically.

Findings – The findings of panel regression initially indicate that the pure TE is higher for conventional banks compared to Islamic banks. However, the Islamic banks are more scale efficient than their conventional counterpart. Macro and micro indicators have different impacts on the both types of efficiency. However, the unique factors that show consistent influence on the efficiency types were loans/finance, non-interest income/finance/liquidity and GDP. Furthermore, the determinants are shaped differently for Islamic and conventional banks when the banking model is controlled for.

Originality/value – This paper examines the efficiency types using a unique window analysis approach to examine the types of efficiency with a longitudinal set of data from 1996 to 2011.

Keywords Panel data, Islamic banks

Paper type Research paper

1. Introduction

Yemen's economy has experienced several difficulties over the last two decades and continues to suffer from ongoing unrest and violent clashes. Yemen's political instability centres predominantly on the conflict between the Government of Yemen and a minority religious (Shi'a) group in northern Yemen, and calls for secession from those living in the south. This complicated and often tumultuous environment has been a formidable ongoing obstacle in the economic development of the country including the financial sector (Shawtari *et al.*, 2014). What is more, recent revolutionary trends have worsened the situation. Consequently, the financial system faces huge challenges in contributing to the economic progress of the nation (Shawtari *et al.*, 2015a, b, 2018). With several reforms having been introduced in the financial system until now, the recent issuance of Sukuk by the government adds to the importance of the banking sector for the country's "advancement in various fields". Islamic banks, though still small in number, have contributed to this expansion and rapid growth since the early 2000s. Reformation of the financial sector and relaxation of foreign entry supplemented with others enhancements in the banking sector could be the main drivers for such expansion.

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With such several structural changes in the banking industry since early 1996, the period after the introduction of Islamic Bank Act in Yemen, the stiff competition aligned with the deregulation and liberalisation of the financial sector has become a challenge for all players. Intensified competition has led to major changes in the structure of the banking sector. Following these trends, Yemeni banking has achieved momentous progress in all indicators.

As far as developing countries are concerned, the banking sector is an important institution that helps enhance the transmission of monetary policy due to the absence of a capital market. A backwards financial system and the legislation of the country as stated by Qatinah have become critical for the banking sector to develop and expand. This is because the underdeveloped financial and legal systems expose the banking sector to the risk of survival for the short and long term. To face the dilemma, the banking sector has to strive to improve its efficiency so as to be able to enhance the economic growth and prosperity of the country. Despite the structural changes, which have taken place in the Yemeni financial system, particularly, the banking sector, research is still in its early stages compared to other neighbouring countries.

This study examines the efficiency trends of Islamic and conventional banks in Yemen by decomposing them into pure technical efficiency (TE) and scale efficiency (SE) in a comparative manner that draws implications for banking practitioners and regulators alike. The paper also examines the determinants of the efficiency of the banking sector in Yemen and how the banking models might influence the behaviour of the micro and macro determinants of the efficiency of banks in Yemen.

The findings of the study indicate that efficiency of banking in Yemen initially indicate that the pure TE of Islamic banks lags behind the conventional banks. However, the Islamic banks are more scale efficient than their conventional counterparts. Macro and micro indicators have different impacts on the both types of efficiencies. The unique factors that report a consistent influence on the efficiency types were loans/finance, non-interest income/finance/liquidity and GDP and the effects are shaped differently for Islamic and conventional banks when the banking models are taken into consideration.

The rest of the paper is organised as follows. The second section of the paper discusses the literature review, followed by the third section of methodology. Section 4 presents the results of the study and Section 5 concludes the paper.

2. Literature review

In the few last decades, the efficiency of the financial sector has become the topic of many studies in both developed (for instance, Webb, 2003; Fiordelisi *et al.*, 2011; Chortareas *et al.*, 2012; Chortareas *et al.*, 2013) and developing economies (for instance, Staub *et al.*, 2010; Tecles and Tabak, 2010; Sufian, 2009). The above studies utilised various approaches to estimate the efficiency with most adopting the standard DEA to examine the efficiency of the banks across the globe (Ahmed Mokhtar *et al.*, 2008; Hassan *et al.*, 2009; Sufian, 2011; Ajlouni *et al.*, 2011; Chortareas *et al.* 2013; Zimkova, 2014; Tsionas *et al.*, 2015). Akhigbe and McNulty (2003) investigated profit efficiency using a unique sample size of small US banks for the 1990–1996 period. They found that the small banks were less efficient than the large banks. Drake (2001) utilised the DEA to test the efficiency of retail banks in the UK during the transition period 1982–1995. Employing production and intermediation approaches for the selection of input and output factors, the results suggested that the overall efficiency of the intermediation approach was 87 per cent and that SE was of greater concern than TE over the study period. Singh *et al.* (2008) examined the efficiency of the top 300 Asia Pacific Banks for 2006. They show that overall TE and SE for New Zealand and Australian banks were greater than others in the analysis (i.e. other Asian countries). Interestingly, Singaporean

banks, though fully efficient with regards to SE, have low TE compared to others in the region.

A recent trend has seen studies investigate the efficiency of banks in a comparative manner. For example, Said (2012) focused on how banking models might have different efficiency levels during the financial crisis of 2008. The study shed light on whether the financial crisis has impacted the Islamic and conventional banks differently. The results of the study find that Islamic banks sustained and performed better than conventional banks during the crisis period.

Recently, Abbas *et al.* (2016) examined the efficiency of banks in Pakistan in a comparative study of Islamic and conventional banks and their determinants utilising standard DEA. Their findings indicated that the efficiency of both Islamic and conventional banks was different, where the performance of Islamic banks is far behind the conventional banks in Pakistan in terms of TE and pure technical efficiency (PTE), while it seems that their SE does not differ.

In contrast, Shawtari *et al.* (2015a, b) showed that Islamic banks in Yemen are more efficient than conventional banks over the period from 1996 to 2011. In different contexts, other researchers have utilised DEA windows to examine the efficiency indicators of banks (Shawtari *et al.*, 2015a, b; Avkiran, 2004; Webb, 2003). Webb (2003) indicated that the efficiency of retail banks in the UK is more towards SE rather than resources wastage (i.e. PTE). Reisman *et al.* (2003) examined the efficiency over time for a sample of banks in Tunisia using DEWA that ownership plays a role in determining the efficiency. Sufian (2007) utilised DEAW and concluded that efficiency of Singaporean banks experienced an improvement in their efficiency scores over time and that the efficiency of large banks was lower than small banks. Avkiran (2004) used the DEWA for a sample of Australian banks and indicated that efficiency of banks in recent observations was better than earlier observations referring that to pure technical inefficiency. Řepková (2014) examined the efficiency of the Czech banking sector using DEWA. The study showed that larger banks are less efficient than small and other banks. The reason is that the larger banks hold huge deposits and inappropriate size of operations.

The above studies expanded their analysis to study the main influencing factors of the efficiency of banks. They divided these factors into macro and micro determinants. Sufian and Majid (2009) determined the profitability and capital and loans as the main determinants. They showed that market power is important for the efficiency of the banks. Other studies utilised factors such as non-performing loans, liquidity risks, non-interest/finance income, required reserve by central banks, and profitability as determinants of efficiency (Shawtari *et al.* 2015b). Gunes and Yilmaz (2016) examined the PTE and SE determinants for Turkish conventional deposit banks. They found that market share and risk negatively impacted the PTE, while size and loan intensity have a positive influence on PTE. The results show that size, risk and bank management quality have negative effects on SE. Inversely, loan intensity and market share profitability influence the SE positively.

Building on the above discussion, there is a lack of studies that examine the efficiency of banks in Yemen with a rare attempt investigating the total efficiency and its determinants by Shawtari *et al.* (2015b), leaving the scope to expand the literature to decompose efficiency into its types and further shed light on their determinants.

3. Research design and empirical model

3.1 Data

The data for this study are collected from the annual reports of the banks for the 1996–2011 period for all banks operating in Yemen. Overall, the sample is consistent with the entire population during the period of study. In all, 16 banks were operating during this period, comprising four Islamic banks and the remaining are conventional.

3.2 Selection of inputs, outputs and approach

The most important consideration in estimating efficiency is the selection of appropriate approach as well as input and output factors (Sufian and Habibullah, 2010; Sufian, 2011). The basic guide in the selection process is to formulate the proper theory of production that is applied to the banking industry, which helps in the process of selecting input and output indicators. Prior research has favoured the intermediation as it fits the nature of banking operations as financial intermediaries. Their main role is to channel the money of depositors to the borrowers using a combination of labour and capital (Drake, 2001; Webb, 2003). Following the intermediation approach and consistent with prior research (Kumar and Gulati, 2009; Shawtari *et al.*, 2015a, b), the paper uses loans/finance ($Y1$), interest/finance income ($Y2$), non-interest/finance income ($Y3$) as outputs, while deposits ($X1$), capital ($X2$) and labour ($X3$) as inputs[1]. These outputs and inputs are selected in line with the intermediation approach of banking functions. It is assumed that banks received deposits as inputs and with labour and needed physical capital processed them into outputs of loans and income generated out of these loans/finance (Sufian, 2009; Webb, 2003). Table I shows the distribution of inputs and outputs.

3.3 Technique adopted: DEWA

Although DEA in its standard version has been utilised by several researches such as Saxena *et al.* (2016) and Sahoo (2016), this study utilises a different version of DEA, which is the DEWA to measure the efficiency of the banking sector in Yemen. It is a non-parametric method used to estimate how the decision-making units (DMUs) perform in comparison to a frontier. This method has several advantages including the ability to evaluate the efficiency relative to a benchmark for a number of firms based on theoretical optimal performance for every organisation (Campisi and Costa, 2008). In addition, the method does not assume functional forms and has the ability to use multiple inputs and outputs (Ahmed Mokhtar *et al.*, 2008). What is of more importance is the appropriateness of the method in cases where the sample size is small in number (Avkiran, 2004; Canhoto and Dermine, 2003; Sufian, 2007). Seiford and Thrall (1990) opined that the method is of a frontier nature rather than central tendency, where it is considered a piecewise linear surface to rest on top of the observations. This method is superior and helps estimate the efficiency of DMU in a relative sense.

Therefore, the paper utilises the DEA but deviates from the standard DEA to adopt the window DEA. The DEWA stands on the concept of moving average principles. It helps the cases when the research interest is to trace the efficiency trends over time (Kisielewska *et al.*, 2005). Charnes *et al.* (1985) introduced DEWA to detect the efficiency trends and variations over time. The method treats each DMU as if it were a different DMU in each period. It contrasts the efficiency scores of DMU with its owns in other periods as well as to other DMUs and subsequently helps to specify the top and worst DMUs and thereof the stability (Halkos and Tzeremes, 2009; Sufian, 2007; Piyu, 1992). The discriminatory power of the method is being enhanced (Avkiran, 2004; Danijela *et al.*, 2012; Halkos and Tzeremes, 2009)

	Outputs (Thousands)			Inputs (Thousands)		
Indicators	$Y1$	$Y2$	$Y3$	$X1$	$X2$	$X3$
Mean	16,222,121	1,701,191	685,791	865,652	562000,781	40,488,379
Max	123,705,863	21,175,364	5,721,121	5,598,282	4,569,830	284,514,068
Min	15,865	941	354	214	4,482	459,229
SD	22,904,822	2,897,143	868,984	1,037,354	716,815	49,282,697

Table I.
Descriptive statistics for outputs and inputs

Notes: $Y1$ is total loan/financing; $Y2$ refers to interest/financing income; $Y3$ represents non-interest income; $X1$ indicates the physical capital; $X2$ is the human capital; $X3$ is total deposits

as it creates sufficient observations and hence the degree of freedom. In line with this argument and consistent with other literature (Shawtari *et al.*, 2015a, Halkos and Tzeremes, 2009; Avkiran, 2004), the three-window analysis will be established. Table AI shows the process of construction of the window analysis.

As can be seen from Table AI, while the first window contains years 1996–1998, the second window comes next by moving on one year by removing the original year 1996 and replacing that by 1999 to build a window of 1997–1999. This process continues until the last window, where the last window contains years 2009–2011. As this method aims to enhance the observation, the total number of windows produced a data points of 581 observations for the entire period. The rule of thumb suggests that the number of DMUs should be at least three times the number of inputs and outputs (Banker *et al.*, 1984; Raab and Lichty, 2002). In the case of the study, the minimum number of DMUs is 32 which is more than enough to meet the criteria suggested by the literature.

3.4 Second stage analysis: panel data econometric model and hypotheses

The main objective of this study is to estimate the efficiency in the first stage using DEWA. It is complemented with a second stage analysis to determine what shapes the efficiency scores of the banking sector. The results of first stage analysis are used as dependent variable in the second stage to be regressed against determinants including internal and external variables (Sufian and Habibullah, 2010). Banker (1993), Banker and Natarajan (2004, 2008) and McDonald (2009) opined that using the second stage helps yield consistent estimators of the regression coefficients. Banker and Natarajan (2008) argued that the use of a two-stage method of testing efficiency which involves DEA, followed by ordinary least square regression, yields consistent estimators of the regression coefficients. Therefore, pooled OLS will be utilised as the baseline regression in this study to test the determinants of efficiency types. However, other robustness cheques will also be undertaken.

As the nature of the data used for this paper is a panel in nature, the panel techniques with unbalanced data are used to regress the determinants of PTE and SE. Fixed and random effects are adopted to count for the firms-specific and time effects to avoid a bias and misspecification of the models. Following the studies that adopted the panel techniques (for instance, Shawtari *et al.*, 2015a, b; Halkos and Tzeremes, 2009; Huang *et al.*, 2012), the following two models will be tested:

$$\begin{aligned}\text{LnPTE} = {} & \alpha + \beta 1\text{Dummy Islamic} + \beta 2\ \text{LN(GDP)} + \beta 3\ \text{LN(INF)} \\ & + \beta 4\ \text{LN(CONC)} + \beta 5\ \text{LN(size)} + \beta 6\text{CAP} + \beta 7\text{ROA} + \beta 8\text{CR} \\ & + \beta 9\text{NII} + \beta 10\text{TLTA} + \beta 10 + \varepsilon,\end{aligned}$$

$$\begin{aligned}\text{LnSE} = {} & \alpha + \beta 1\text{Dummy Islamic} + \beta 2\ \text{LN(GDP)} + \beta 3\ \text{LN(INF)} \\ & + \beta 4\ \text{LN(CONC)} + \beta 5\ \text{LN(size)} + \beta 6\text{CAP} + \beta 7\text{ROA} + \beta 8\text{CR} \\ & + \beta 9\text{NII} + \beta 10\text{TLTA} + \beta 10 + \varepsilon.\end{aligned}$$

The summary of the above variables' definitions and their operationalisation that are included in the models are depicted in Table II.

Building on our models, we develop certain hypotheses to test the models. The literature survey shows few indications of the expected relationship between the dependent and independent variables.

The first relationship proposed in the above models is with regard to the efficiency differentiation between Islamic and conventional banks. The dummy Islamic bank in the model is meant to show whether we can differentiate between Islamic and conventional

Variable short form	Variable name	Operationalisation of the variable
LnPTE	Natural logarithm of pure technical efficiency	Estimation using DEAW
LnSE	Natural logarithm of scale efficiency	Estimation using DEAW
Dummy Islamic	Dummy Islamic Banks	1 for Islamic banks, 0 for conventional banks
Ln (GDP)	Economic growth and development	Natural logarithm of growth domestic product as released by IMF
Ln (Inf)	Inflation index	Natural logarithm of consumer index as released by IMF
Ln (CONC)	Market concentration	Natural logarithm of the assets of largest three banks in the industry
Ln (size)	Size of the bank	Total assets of the bank
Ln (Cap)	Capitalisation of the bank	Natural logarithm of capital/the total assets
Ln (ROA)	Return of assets	Natural logarithm of profitability of the banks. It is measured as net income/total assets
Ln (CR)	Credit risk	Natural logarithm of loan/finance loss provision to total loans/finance
Ln (NII)	Non-interest income	Natural logarithm of total of non-interest income
Ln (TL)	Total loans	Natural logarithm of the total loans for conventional banks and total finance in case of Islamic banks
Ln (LIQ)	Liquidity	Natural logarithm of Liquid assets/liabilities

Table II.
Summary of the variables

banks' efficiencies. We expect that Islamic banks are less efficient either in term of PTE or SE. This is because of their relatively short history and the higher operation costs arising from developing and introducing new instruments. In contrast, the conventional banks are very well developed with long history and experience in the market, and they have the advantages of economy of scale in the market to produce at lower costs compared to Islamic banks (Ahmed Mokhtar *et al.*, 2008). Therefore, we hypothesise that:

H1. The conventional banks are more efficient than Islamic banks in Yemen.

With respect to the second variable, which is GDP as an indicator of economic growth and development, in line with Sufian and Habibullah (2010), we expect that it would have a positive influence on the demand for the loans and financing from the banks, which influence the efficiency. Thus, the following hypothesis is proposed:

H2. The GDP is related positively to the levels of efficiency of the banks.

The third aspect of the determinants of efficiency is inflation (INF). Inflation is argued to be relevant to the efficiency indicators in the view of Boyd *et al.* (2001) and Ben Naceur and Ghazouani (2005) who suggested that as inflation levels rise, the adverse effects on economic growth are expected, particularly in the financial sector. This is because economic growth positively affects the financial sector performance (Barro, 1995). As such, the following hypothesis is proposed:

H3. Inflation is positively related to the efficiency of the banks.

The market concentration (CONC) is another indicator that is assumed to be relevant for efficiency evaluation. The level of concentration in the banking industry would positively influence the efficiency of banks due to the ability of banks to collude and earn monopoly profits (Pasiouras and Kosmidou, 2007). This leads to the following hypothesis:

H4. The higher concentration of the industry is positively related to the efficiency levels of the banks.

The size of the bank is another key indicator that may influence the efficiency of the banks. Size is expected to be related to efficiency positively benefiting from the economies of scale (Sufian and Habibullah, 2010). In line with this, we develop the following hypothesis:

H5. The size of the banks is positively related to the efficiency levels of the banks.

The capitalisation (CAP) of the banks is yet another important determinant of the banks' level of efficiency. It is an indicator of the capital structure of the banks and a very sensitive factor as well-capitalised banks are more likely to be strong and can resist in times of crisis. Thus, gaining more confidence from the side of depositors who will be more comfortable to save with these banks affects the performance positively (Sufian, 2009). In this respect, the following hypothesis is postulated:

H6. Well-capitalised banks are more efficient than less capitalised banks.

Profitability (ROA) is expected to be related to the efficiency of the banks. The argument is that the profitable banks are more likely to attract depositors, which provides more incentives for the profitable banks to gain more and become more efficient compared to others (Sufian and Habibullah, 2010). Thus, we hypothesise that:

H7. The profitability is positively related to the efficiency of the banks.

Next, the credit risk (CR) is expected to influence the efficiency. Higher loan/finance loss provision is related low efficiency. This can be understood from the fact that the bad loans/finance lead to higher by loan/finance loss provision affecting the efficiency of banks negatively (Miller and Noulas, 1997). Thus, we hypothesise the following:

H8. Credit risk is negatively related to the efficiency levels of the banks.

Non-interest income is among the bank-specific indicators associated with the efficiency levels of the banks. It represents a large portion of the income of the banks as diversification of business is important for efficient operations (Sufian, 2009). In such a way, the following hypothesis is formulated:

H9. The non-interest income is positively related to the level of efficiency.

Total loans are a significant factor affecting the efficiency of the banks. TLTA represents the total loans for conventional banks and total finance in the case of Islamic banks. The banks with higher loans/finance would enjoy the better market power, and hence the efficiency will be maximised (Sufian and Habibullah, 2010). Based on that, the following hypothesis is developed:

H10. Loans is positively related to the levels of efficiency.

Finally, liquidity (LIQ) is an indicator frequently linked with efficiency. Liquidity risk premium reflects the risk of the banks. Although a higher ratio indicates the ability of banks to operate with less borrowing costs and also boosts confidence among the depositors that they are safe (Donkor and Kodua, 2013), high liquidity may also indicate tied up investment and inability of the banks to translate the depositors' money into loans/finance, which will be reflected in lower efficiency (Poghosyan, 2013). The following hypothesis is proposed:

H11. The liquidity ratio is negatively related to the efficiency levels of the banks.

To estimate the above two models, we adopted the panel data techniques with fixed and random effects with standard errors corrections for heteroscedasticity and autocorrelation. The use of an appropriate method of analysis requires certain diagnostics tests to validate the power of each test. The main advantage of the panel data method is considered to be an

efficient estimation method where it allows the inclusion of data for N cross-sections (example, banks) and T time periods (years). Therefore, the number of observations available increases over time (Asteriou and Hall, 2007). As the panel data give the researcher a large number of data points, the degree of freedom will be increased, and the collinearity among the variables will be reduced, thereby improving the efficiency of econometric estimates (Hsiao, 2003, p. 3). The three relevant panel-applied techniques in this exercise comprise the pooled OLS, fixed effects and random effects. The choice of this static panel data rather than dynamic panel data is explained by the nature of the data in which the time is very long (Asteriou and Hall, 2007). The dynamic panel is more suitable in cases where the period T is shorter than N.

Due to the fact that the data set is not homogeneous in most cases, a robustness test using fixed effect and random effects will also be undertaken. This is because, in using the panel data, the consistent estimation of the equation by OLS is difficult, as the error terms are no longer homoscedastic. If the errors are not homoscedastic, OLS estimates will be consistent but inefficient. Thus, the reported standard errors will be incorrect. Fixed and random effects models can help solve this heteroskedastic problem. The advantage of fixed effects and random effects over pooled OLS is that both methods allow for differences in data sets. Fixed effects capture the effects particular to an individual unit and which do not vary over time. On the other hand, random effects deal with constants for each section, not as a fixed but as a random parameter. The main advantage of random effects is that it has fewer parameters to estimate compared to fixed effects (Asteriou and Hall, 2007).

4. Results of the study

4.1 Summary statistics and the general trends of efficiency types

This section presents the summary statistics of efficiency scores and estimates for the period of investigation. As indicated in Table I, the summary of average efficiency, the average overall efficiency for the banking sector from 1996–2011 was 69 per cent; an indicator of underperformance of the banking sector and the waste of resources was evidenced during this period. The waste reaches a higher percentage of almost one-third or 31 per cent. The less dependence on the banking sector to finance economic development due to high standards of lending and financing would be the main reason behind the low ratio of loans deposits in the banking sector. This highly influences the efficiency of the banks. When decomposing the efficiency into PTE and SE, Table III shows that the Yemeni banking sector suffers heavily from PTE rather than SE with 67 per cent for the former and 86 per cent for the latter. In other words, the inefficiency due to wasting the resources is almost 33 per cent, while the inefficiency due to scale is only 14 per cent.

Table IV shows the PTE and SE average scores for all banks. In general, the Yemeni banking sector was more "pure technical inefficient" than "scale inefficient". In addition, it can be seen in Figure 1 that pure technical inefficiency (inputs related) outweighed SE (outputs related) in Yemen. This suggests that the Yemeni banking sector lacks the capabilities to manage its inputs efficiently.

Table III. Average efficiency for all banks by years 1996–2011

Bank	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	200	2009	2010	2011	Mean/ Year
Eff. annual mean																	
TE	0.80	0.76	0.74	0.74	0.65	0.58	0.64	0.67	0.64	0.74	0.67	0.76	0.71	0.60	0.66	0.69	0.69
PTE	0.58	0.58	0.55	0.72	0.58	0.67	0.72	0.69	0.70	0.74	0.66	0.73	0.78	0.69	0.73	0.67	0.67
SE	0.90	0.94	0.95	0.86	0.85	0.81	0.90	0.95	0.93	0.98	0.92	0.93	0.81	0.86	0.79	0.84	0.89

Windows banks	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	Mean windows
NBY	0.31	0.41	0.60	0.42	0.23	0.29	0.34	0.36	0.54	0.68	0.72	0.71	0.50	0.56	0.48
CBY	0.97	0.85	0.80	0.83	0.73	0.59	0.56	0.54	0.47	0.52	0.46	0.52	0.48	0.46	0.63
CAC	0.98	0.82	0.80	0.75	0.86	0.79	0.73	0.46	0.37	0.40	0.44	0.63	0.55	0.55	0.65
YDR	0.97	0.95	0.79	0.74	0.78	1.00	1.00	1.00	1.00	0.78	0.88	0.82	0.75	0.49	0.85
IBOY	1.00	1.00	0.92	0.80	0.85	0.74	0.75	0.73	0.88	0.89	0.73	0.68	0.76	0.87	0.83
KBI	1.00	1.00	0.92	0.80	0.85	0.74	0.75	0.73	0.88	0.89	0.73	0.68	0.76	0.87	0.83
QATAR												0.92	0.80	0.65	0.79
ARABB	0.77	0.55	0.46	0.43	0.40	0.41	0.44	0.49	0.55	0.66	0.73	0.97	0.83	0.63	0.59
RAFIDEN	1.00	1.00	0.97	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99
ULB		1.00	1.00	0.99	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.99
CALB		1.00	0.84	0.97	0.88	0.97	0.91	0.84	0.94	1.00	0.99	0.93	0.91	0.57	0.90
GULFB			1.00	1.00	0.92	0.93	0.90	0.90							0.94
TADH	0.88	0.89	0.94	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.99	1.00	0.97
SABA	1.00	1.00	0.84	0.72	0.56	0.54	0.63	0.60	0.62	0.74	0.77	0.91	0.96	0.96	0.77
IBOD	0.83	0.73	0.92	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96
SHAMIL						0.59	0.63	0.63	0.69	0.68	0.76	0.82	0.83	0.70	0.70
Mean/ Window	0.88	0.86	0.84	0.81	0.79	0.77	0.78	0.75	0.78	0.80	0.80	0.84	0.81	0.75	
Overall mean pure efficiency, all windows															0.80
Average pure efficiency Windows 1–7															0.82
Average pure efficiency Windows 1–14															0.79

Table IV.
Pure technical efficiency

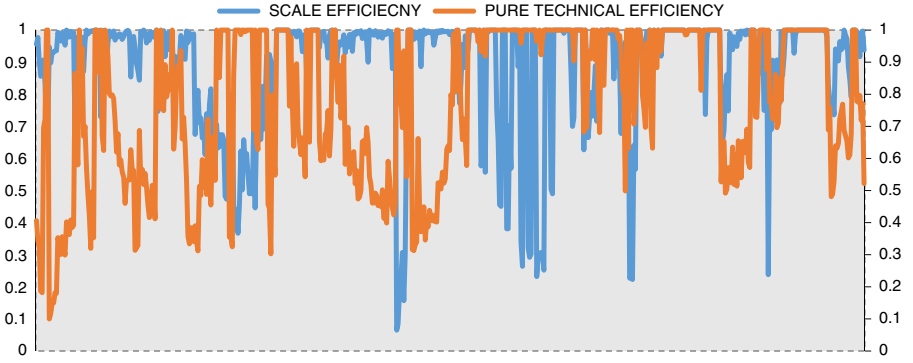

Figure 1.
Pure technical vs scale efficiency

Prior literature has suggested that larger banks tend to report higher levels of PTE than their smaller counterparts (Berger *et al.*, 1993; Drake, 2001; Webb, 2003; Sufian, 2007). In other words, the level of inefficiency is lower for larger banks. The overall mean of PTE for all windows revolved around an average of 80 per cent. However, the mean of pure technical inefficiency for Windows 1–7 was 18 per cent, which is lower than 21 per cent in the latter period covered by Windows 8–14[2]. This indicates that technical inefficiency has increased over time. The lower levels of PTE could be due to the high level of concentration and the lack of competition in the Yemeni banking sector, as argued by Sathye (2001). Due to the dominance of three banks in the sector with almost half of the market share, Walker (1998) suggested that "quiet life" hypothesis which laid down that market power and concentration would lead to inefficiency not because of uncompetitive prices, but because of the absence of incentives to minimise resources wastages. As such, pure technical inefficiency is clearly the dominant source of inefficiency of the Yemeni banking sector.

Furthermore, the analysis based on ownership, as shown in Figure 2, reveals that foreign banks were the most efficient in terms of input minimisation, while state-owned banks were the least efficient. Islamic banks are on track in terms of input minimisation, as can be seen from their progress in the enhancement of PTE (Figure 2). In sum, Islamic and foreign conventional banks show a TE uptrend, whereas the state-owned and local private conventional banks exhibit a downtrend in their efficiency as reflected in their inefficiency scores (Figure 3).

The second component of overall efficiency is the SE, which is related to the economies of scale. Table V gives the average overall SE across windows. Overall, the average SE scores for the Yemeni banking sector hover around 91 per cent, which suggests that banks in Yemen are quite efficient in terms of scale.

As shown in Table V, the International Bank of Yemen (IBOY) is almost on the frontier, with an average SE score of 99 per cent (SD: 2 per cent), followed by Tadhamon Islamic Bank and Arab Bank with SE scores of 98 per cent (SD: 5 per cent) and 96 per cent (SD: 5 per cent), respectively. This is not consistent with the literature that reported that larger banks tend to

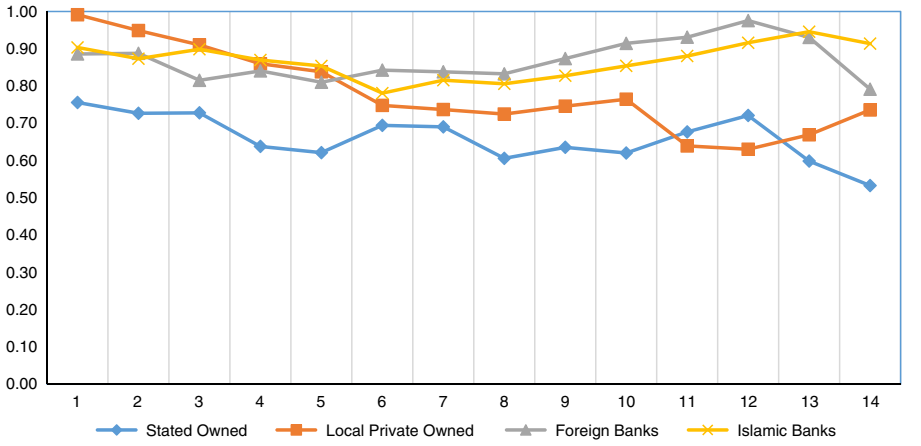

Figure 2.
Pure technical efficiency across ownership models

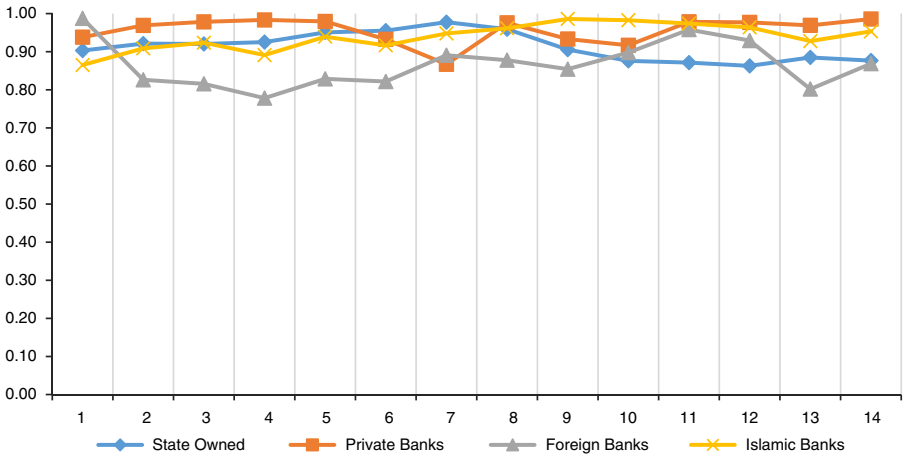

Figure 3.
Scale efficiency by ownership types

	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	Mean/ Windows
NBY	0.93	0.86	0.83	0.85	0.95	0.97	0.98	0.98	0.88	0.90	0.92	0.98	1.00	1.00	0.93
CBY	0.89	0.96	0.95	0.98	0.98	0.98	0.99	0.95	0.96	0.91	0.96	0.99	0.97	0.99	0.96
CACB	0.89	0.96	0.95	0.98	0.98	0.98	0.99	0.95	0.96	0.91	0.96	0.99	0.97	0.99	0.96
YDRB	0.89	0.94	0.97	0.95	0.92	0.92	0.96	0.95	0.88	0.82	0.74	0.62	0.69	0.64	0.85
IBOY	1.00	1.00	1.00	1.00	0.99	0.97	0.93	0.99	1.00	0.98	1.00	0.96	0.98	1.00	0.99
YKBI	0.93	0.95	0.98	0.98	0.97	0.99	0.98	0.96	0.99	0.99	0.98	0.99	0.95	0.97	0.97
QATAR												0.112	0.23	0.52	0.29
ARABB	0.99	0.99	0.95	0.99	1.00	0.98	0.99	1.00	0.99	1.00	0.97	0.84	0.86	0.95	0.96
RAFEDEEN	0.98	1.00	0.85	0.72	1.00	1.00	0.88	0.74	0.61	0.65	0.90	1.00	0.74	0.69	0.84
ULB		1.00	0.81	0.89	0.79	0.78	0.94	0.98	0.98	0.95	0.97	0.93	0.71	0.93	0.90
CALB		0.32	0.65	0.51	0.53	0.53	0.75	0.80	0.83	1.00	1.00	0.96	0.90	0.91	0.74
GULFB					0.23	0.44	0.59	0.98	0.98	0.96					0.70
TIB	0.96	0.92	0.98	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.87	0.99	0.98
SABA	1.00	1.00	0.93	0.82	0.85	0.90	0.96	0.97	1.00	0.99	0.96	0.93	0.85	0.88	0.93
IBOD	0.63	0.81	0.86	0.88	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.94
SHAMIL						0.79	0.84	0.87	0.95	0.94	0.94	0.93	0.99	0.95	0.91
Mean/Window	0.92	0.90	0.90	0.89	0.87	0.88	0.92	0..94	0.93	0.93	0.93	0.95	0.88	0.85	
Overall mean scale efficiency, all windows															0.91
Average scale efficiency windows 1–7															0.90
Average scale efficiency windows 8–14															0.92

Table V.
Scale efficiency

have lower levels of SE (Miller and Noulas, 1997; Drake, 2001; Webb, 2003; Sufian, 2007). Drake (2001) opined that SE might not be a function of size, and it may be related to the nature of a bank, its business mix, focus and overall strategy. The worst performer in term of SE score is the Qatar National Bank, followed by the Gulf Bank, with mean SE scores of 29 and 70 per cent, respectively. This low level of SE could be due to their small assets (YR 12bn and YR 20bn, respectively) and their short history as their incorporation was fairly recent. The Rafideen Bank, another small bank, also experienced a lower SE of 84 per cent (SD: 14 per cent). A plausible reason for the lower SE in the case of the Rafideen Bank is its small size with average assets of YR 6bn for the entire period, and YR 15bn for 2011.

Surprisingly, all large banks reported higher levels of SE, with the exception of Kaluin (a foreign bank) which reported a lower SE score of 74 per cent, despite its large size with assets of YR 106bn in 2010.

Although the results are not in sync with the literature where the large banks have high inefficiency scores, it is not the norm for large banks in Yemen. The reasoning by Drake (2001) could explain part of the variation in the results of SE across the Yemeni banking sector. As mentioned previously, Drake (2001) contended that SE score might not be a function of size alone, as other factors could also play a role.

Further analysis is conducted to compare the SE scores of banks of different types, to compare state-owned, local private-owned, foreign and Islamic bank scale efficiencies. Figure 3 shows that the average SE of the four private-owned banks revolved around 96 per cent indicating that those banks are the most scale efficient in the industry. Furthermore, their SE exhibits a slight increase in the later windows compared to the early windows. Islamic banks trailed the private conventional banks with an SE score of 94 per cent, but with an uptrend in SE in the later period to 96 per cent. The results apply to small Islamic banks and larger Islamic banks with small differences in their SE which is consistent with the findings of Drake (2001) and Webb (2003) in the context of the UK banking sector where they suggest that SE may not be a function of size alone. In contrast to Islamic and private banks, state-owned banks exhibit a deterioration in the SE over time,

with specific reference to Windows 9–14, although they are still more scale efficient than foreign banks. However, foreign banks' SE is largely affected by Rafdeen and QNB which have lower levels of SE among the foreign banks.

4.2 Efficiency results: Islamic vs conventional banks

As mentioned previously, different types of tests will be used to test the hypotheses. The first main compares efficiency scores across different types of banks with an emphasis on efficiency comparison between Islamic and conventional banks in Yemen. Following prior studies (for instance, Sufian, 2007; Ahmad and Abdul Rahman, 2012; Isik and Hassan, 2002), both parametric tests and non-parametric tests are undertaken to test the hypothesis that Islamic banks are less efficient than conventional banks.

As shown in Table VI, the results of both parametric and non-parametric tests indicate that TE, PTE and SE tests of difference between Islamic and conventional banks are not of the same order over three types of efficiency. However, it was found that Islamic banks are more efficient and outperformed their counterparts in overall efficiency scores and SE. However, it indicates a lower PTE for Islamic banks. Thus, the results do not fully support the stated hypothesis in this study which proposes that conventional banks are more efficient than Islamic banks. Hassan *et al.* (2009) showed that cost, profit and revenue efficiency in Islamic and conventional banks were similar in GCC. Ahmad and Abdul Rahman (2012) found that conventional banks in Malaysia were more efficient than Islamic banks in term of TE and SE, which contradicts the results of this study. Their study also suggested that both conventional and Islamic banking models were similar in terms of input wastage which is consistent with this study. The results of this study where Islamic banks revealed to be overall more efficient can be explained by the nature or the psyche of the Yemeni people who find Islamic banks more attractive and appealing due to their religious values and traditions. This is favourable to the Islamic banks' operations in term of deposits and financing, which bode well for their expansion.

4.3 Panel techniques estimation results

To examine the determinants of each type of efficiency, we have utilised panel data techniques. We have used essentially the OLS and its estimators with various diagnostic tests for heteroskedasticity and serial autocorrelation. The Breusch–Pagan/Cook–Weisberg test and White (1980) test show the existence of heteroskedasticity at the 1 per cent level of significance. We also utilise the Wooldridge (2002) test to check the likelihood of serial correlation existence. Overall, the results indicated the presence of serial autocorrelation under 10 per cent level of significant. Furthermore, the correlation test has been employed

Table VI. Test of difference between Islamic and conventional banks efficiency scores, all windows

	Parametric tests		Non-parametric tests	
Individual tests	Analysis of variance (ANOVA) test	*t*-test	Kilmogogrov–Smirnov (K-S) test	Mann–Whitney (Wilcoxon Rank–Sum) test
Hypotheses	Mean IBs − Mean CBs *F (*Prob > *F)*	Mean IBs = Mean CBs *T* (Prob > *t)*	Mean IBs = Mean CBs *K-S (Prob > K-S)*	Median IBs = Median CBs Median (Prob > *t*)
TE	64.92 (0.00)*	−8.058 (0.04)**	3.361 (0.000)*	−7.759 (0.000)*
PTE	26.82 (0.000)*	−5.179 (0.00)*	−2.251 (0.000)*	−5.108 (0.000)*
SE	19.93 (0.00)*	4.381 (0.00)*	3.089 (0.000)*	−5.539 (0.000)*

Notes: The number in parentheses are the *p*-values associated with relative test. *,**Indicates significant difference at 1 and 5 per cent level, respectively

using the Pearson correlation matrix as shown in Table VII. The indicator of the test shows that collinearity is less likely to be a problem among the regressors.

As far as the data of this study are a panel, it is significant to choose the right method of panel technique to be used and interpret the results given the chosen method. The diagnostic test of Lagrange Multiplier (LM) test (Breusch and Pagan, 1980) is conducted to decide whether the pooled OLS or random effects is appropriate. The LM test suggests that random effects are more powerful than pooled OLS, and therefore, the findings will be interpreted based on the results of random effects[3]. Since the data suffer from the problem of the presence of heteroskedasticity as shown by Breusch-Pagan/Cook-Weisberg and White (1980) tests of heteroscedasticity and the existence of the autocorrelation as indicated by the Wooldridge (2002) test, it is important to ensure a valid statistical inference by relying on robust standard errors to solve the problem of heteroskedasticity and autocorrelation, so that the results will be more robust (Asteriou and Hall, 2007). As such, the models are run with Rogers' (1993) standard errors correction for both heteroscedasticity and autocorrelation[4].

Table VIII shows the results of random effects models. Panels A and B show the results for Models 1 and 2 using polled OLS and random effects. Model 1 is the determinants of PTE and Model 2 the determinants of SE. However, the results will be explained and interpreted using random effects since the diagnostic test shows the superiority of pooled OLS.

The results of the test show that PTE of Islamic banks is lower than conventional banks. However, their SE is higher than conventional banks as can be inferred from the results of the dummy Islamic bank variable shown in Panel B, Models 1 and 2, of Table VIII. The results of PTE are consistent with other results reported by Johnes *et al.* (2013) which showed that Islamic banks were less efficient compared to conventional banks. Majeed and Zanib (2016) found conventional banks to be highly pure and technically efficient. It is attributed to their decreasing cost due to economies of scale and less experience, less developed products and history to exploit the resources appropriately. However, in terms of SE, they are better as they might benefit from the scale effects to gain better market share. The reason is that the Islamic banks have better acceptability among the customers due to the religiosity of the people and their redundancy to accept conventional banks (Shawtari *et al.*, 2015a).

In respect to the influence of the macroeconomic variables on the PTE and SE of Models 1 and 2 in Panel B, Table VIII shows that GDP influenced the efficiency negatively at 10 per cent level of significance. The results are logical and consistent and Rashid and Jabeen (2016) who argued that less investment and less production during the period of good economic conditions, firms and other borrows rely less on the banks to get funds as they would have enough internally generated funds and this might lead the banks to lend at less favourable terms and conditions. This affects the performance and efficiency negatively. Inflation and concentrated index do not have an impact on either type of efficiency.

Variable	GDP	INF	C3	SIZE	CAP	ROA	CR	NII/TA	TL/TA	LIQ
GDP	1.00									
INF	0.02	1.00								
C3	−0.24	0.50	1.00							
SIZE	0.56	−0.02	−0.13	1.00						
CAP	0.19	0.04	0.04	−0.29	1.00					
ROA	0.13	0.03	−0.01	−0.04	0.27	1.00				
LLP/TL	−0.12	0.00	0.03	−0.21	0.27	0.07	1.00			
NII/TA	0.01	−0.02	0.01	−0.15	0.29	0.12	0.04	1.00		
TL	−0.13	0.01	−0.02	−0.04	−0.18	−0.22	−0.28	−0.03	1.00	
LIQ	0.08	0.12	0.03	0.51	−0.23	0.19	0.08	0.41	0.11	1.00

Table VII. Correlation matrix

Variable	Panel A: pooled OLS Pure technical efficiency model (1)	Scale efficiency model (2)	Panel B: random effects Pure technical efficiency model (1)	Scale efficiency model (2)
Macroeconomic indicators				
LN(GDP)	0.03 (0.61)	0.08 (2.37)**	*−0.11* (*−1.69*)***	*−0.08* (*−1.69*)***
LN(INF)	−0.02 (−0.53)	0.00 (0.09)	0.01 (0.29)	0.01 (0.62)
LN(C3)	0.33 (0.88)	0.30 (1.06)	0.04 (0.14)	0.03 (0.14)
Bank-specific characteristics				
LN(SIZE)	−0.02 (−0.52)	−0.20 (−5.50)*	−0.04 (−0.66)	*−0.12* (*−2.72*)*
LN(CAP)	−0.01 (−0.16)	−0.15 (−4.28)*	0.04 (0.85)	0.03 (1.08)
LN(ROA)	0.01 (0.17)	0.02 (1.28)	0.01 (0.29))	*0.03* (*2.18*)**
LN(LLP/TL)	−0.02 (−1.43)	0.01 (0.86)	0.00 (−0.02)	−0.00 (−0.36)
LN(NII/TA)	0.05 (2.98)*	−0.09 (−4.01)*	*0.11* (*4.92*)*	0.01 (0.50)
LN(TL)	−0.03 (−1.95)**	0.15 (5.56)*	*0.02* (*0.58*)	*0.16* (*8.20*)*
LN(LIQ)	0.44 (9.73)*	−0.09 (−2.59)*	*0.41* (*7.43*)*	*0.08* (*1.94*)**
Dummy Islamic	−0.11 (−2.17)*	0.13 (4.11)*	*−0.20* (*−1.96*)**	*0.22* (*3.33*)*
Overall R^2	*0.26*	*0.37*	*0.08* *0.14*	*0.08*
Within R^2			*0.004* *0.17*	*0.59*
Between R^2			*0.132* *0.17*	*0.26*

Notes: The number in parentheses are the standard errors. GDP is the macroeconomic measure of the soundness of economy; INF measures the price index; C3 refers to the concentration index; size is measured by total assets; CAP is the total equity to total assets; ROA measures the profitability; LLP/TL represents the credit risk; NII/TA measures the non-interest/finance income; TL measures the intensity of loans/ finance provided to customers; LN(LIQ) refers to liquidity risks, and finally dummy Islamic is used to differentiate the efficiency of Islamic and conventional banks. *,**,***Significant at 1, 5 and 10 per cent level, respectively

Table VIII.
The determinants of efficiency types

With regards to bank-specific characteristics, size has a significant negative impact at 1 per cent level of significance on SE, suggesting that larger banks suffer from inefficiency, which is consistent with Pasiouras and Kosmidou (2007) and Johnes *et al.* (2013). It is contrary to the findings of Rashid and Jabeen (2016), Sufian and Kamarudin (2016) and Pasiouras and Kosmidou (2007) who argued that the economies of scale and scope for the smaller banks to grow, expand and gain are better than larger banks, where only smaller banks can benefit from economies of scale up to certain sizes beyond which it would be disadvantageous. Al-Gasaymeh (2016) argued that banks in developing countries suffer from the size constraints as it would impede them from the best allocation of resources to investments necessary to help them in promoting themselves and reducing their costs. Furthermore, it can be argued that smaller banks be forced to compete for the survival in the market.

Profitability indicator is another factor that influences the SE positively but has no relationship with PTE. It can be argued that higher profitability can be related to larger banks. However, it does not mean that higher profitable banks are more efficient because efficiency is not the same as profitability (Shawtari *et al.* 2015b). This is one of the shortcomings of profitability measures. Larger banks can enjoy higher profitability and higher SE, which allows the banks to grow larger in size. With respect to NII/NFI, the results indicate that the higher NII/NFI, the higher PTE, which is logically explained by the fact that higher NII/NFI indicates higher outputs which would lead to better utilisation of the resources. The results support the findings of Sufian and Kamarudin (2016).

Isik and Hassan (2003) found that TL/TA is positively related to efficiency at 1 per cent level of significance. This suggests that as loans increase in size, the output would increase and with it the efficiency. Both types of efficiency are positively significantly related to loans. Bank loans are assumed to be the main source of revenue and are expected to affect performance positively. The market power may be the result of

efficient operations. According to Sufian (2009), the ability to manage operations more productively would result in decreased production costs and increased market power over inefficient banks.

Isik and Hassan (2003) argued that the positive relationship between loan activity and bank efficiency may be attributed to the ability of the relatively efficient bank to manage operations more productively, which enables them to have lower production costs and offer more reasonable loan terms. This allows them to gain a larger market share in the loan market segment. Finally, liquidity is related positively and negatively to both types of efficiency. The bank with more liquid resources would be able to generate more loans, and hence loans would be reflected in efficiency improvements. Furthermore, more liquidity indicates the less risk premium as the need to borrow would be lower, which will be reflected in the margin of the banks and their efficiency.

4.4 Further analysis: does banking model matter?

To have a robustness check on whether the behaviour of the determinants of each type of efficiency does not differ whenever the banking model differs, we have run further robustness cheques using a fixed effects model. This is because, in the financial system, there exist different types of banking models and ownership that might shape the banking to behave differently. Banks with different models can react in different ways in response to certain determinants as their structure, and underlying theoretical framework are different. To capture the effects of different banking models, an alternative regression model is employed by interacting effects between the determinants and Islamic banks (a dummy variable that takes 1; 0 otherwise). This model will be run using Islamic bank dummy interactively with the determinants of each type of efficiency. To proceed with either random effects or fixed effects, we have used the Hausman specification test (Hausman, 1978), which compares a random effect model to its fixed counterpart. The test shows the superiority of fixed effects over random effects. The results of this section are presented and explained based on fixed effects.

Table IX reports the findings of interaction effects for the PTE model, while Table X shows the interaction effects for SE model. Overall, the paper provides a thorough analysis by providing a series of models to show a comprehensive picture of the behaviour of the efficiency variables with other macro and micro economic variables. As indicated in Table IX, the statistical significance of the variables in Models 1 through to 4 remains the same, suggesting that the behaviour of each determinant, namely size of the bank, capitalisation (CAP), ROA and credit risks, is not different in each banking model in relation to PTE. However, as in Model 5 with regard to the interaction of NII/NIF, it shows a negative sign and indicates that NIF affects the PTE of Islamic banks negatively, while it has a positive impact on the efficiency of conventional banks. Model 6 also shows that the behaviour of loans/financing is not the same for conventional and Islamic banks. The result indicates a reverse sign, where the finance is negatively related to the PTE, while it is positively related to conventional banks' PTE. In other words, the loans/finance affects the PTE of Islamic banks negatively, which is contrary to the effects on the PTE of conventional banks. Lastly, liquidity shows a positive influence on conventional banks' PTE, while it is not related to the PTE of Islamic banks.

Further analysis has been conducted with regard to SE and the behaviour of Islamic and conventional banks with regard to the determinants of SE. As shown in Table X concerning the behaviour of various determinants of SE, it is noted that size effects behave differently for Islamic and conventional banks. The size has no impact on the overall SE for the entire industry combining them together. However, the size of the Islamic banks behaves differently with a significant and negative sign. This indicates that the bigger the Islamic bank, the lower its SE. Presumably, this can be explained by the fact that size effect can be advantages up to certain levels only, beyond which it would be disadvantageous.

Table IX.
Pure technical efficiency determinants based on fixed effects

Variable	Model 1	Model 2	Model 3	Model 44	Model 5	Model 6	Model 7
LN(GD	*−0.18* (*−1.93*)**	*−0.19* (*−2.11*)**	*0.18* (*−1.97*)**	−0.18 (−1.98)**	−0.17 (1.90)***	*−0.15* (*−2.37*)*	0.17 (−1.88)***
LN(INF)	0.02 (0.55)	0.02 (0.72)	*0.02* (*0.55*)	0.02 (0.56)	−0.02 (0.82)	−0.02 (0.92)	−0.02 (0.54)
LN(C3)	−0.03 (−0.09)	−0.02 (−0.08)	−0.01 (−0.02	−0.01 (−002)	−0.09 (−0.30)	−0.10 (−0.47)	0.05 (0.16)*
Ln(SIZE)	−0.11 (−1.24)	−0.06 (0.72)	−0.08 (−0.99)	−0.08 (0.97)	−0.07 (−0.84)	0.02 (0.30)	−0.08 (0.95)
Ln(CAP)	0.04 (0.83)	0.01 (0.13)	0.04 (0.08)	0.04 (0.77)	−0.04 (0.038)	−0.03 (0.62)	−0.047 (0.35)
Ln(ROA)	0.01 (0.33)	0.03 (0.08)	0.01 (0.08)	0.01 (0.12)	0.01 (0.31)	0.02 (1.50)	0.01 (0.11)
Ln(LLP/TL)	0.02 (0.06)	−0.01 (0.13)	−0.02 (0.05)	−0.01 (0.12)	−0.01 (−0.18)	*−0.02* (*−1.78*)***	0.01 (0.02)
Ln(NII/TA)	*0.15* (*5.27*)*	*0.16* (*5.82*)*	*0.15* (*5.60*)*	*0.15* (*5.92*)*	*0.21* (*6.51*)*	*0.11* (*5.33*)*	*0.15* (*5.44*)*
Ln(TL/TA)	*0.07* (*1.65*)***	*0.08* (*1.96*)**	*0.07* (*1.82*)***	*0.07* (*1.78*)*	*0.08* (*2.01*)**	*0.15* (*4.72*)*	*0.06* (*1.56*)
Ln(LIQ)	*0.41* (*6.81*)*	*0.41* (*6.71*)*	*0.42* (*6.90*)*	*0.42* (*6.92*)*	*0.45* (*7.41*)*	*0.19* (*4.62*)*	*0.37* (*5.56*)*
IB × LnSIZE	0.07 (0.84))						
IB × LnCAP		0.17 (1.55)					
IB × LnROA			0.01 (0.04)				
IB × LnLLp/TL				0.01 (0.04)			
IB × LnNII					*−0.17* (*−3.17*)*		
IB × LnTL						*−0.13* (*3.13*)*	
IB × Ln(LIQ)							0.18 (1.36)
Overall R^2	0.09	0.03	0.08	0.10	0.08	0.09	0.10
Within R^2	0.16	0.16	0.16	0.16	0.18	0.16	0.16
Between R^2	0.08	0.02	0.10	0.08	0.06	0.08	0.08

Notes: The number in parentheses are the standard errors. GDP is the macroeconomic measure of the soundness of economy; INF measures the price index; C3 refers to the concentration index; size is measured by total assets; CAP is the total equity to total assets; ROA measures the profitability; LLP/TL represents the credit risk; NII/TA measures the non-interest/ finance income; TL measures the intensity of loans/ finance provided to customers; LN(LIQ) refers to liquidity risks. *,**,***Significant at 1, 5 and 10 per cent level, respectively

Table X.
Scale efficiency determinants based on fixed effects

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
LN(GD	*0.15* (*−2.37*)**	*0.15* (*−2.37*)**	*−0.15* (*−2.25*)**	*−0.14* (*−2.22*)**	−0.12 (−2.12)**	*0.15* (*−2.37*)**	*−0.14* (*−2.22*)**
LN(INF)	0.02 (0.86)	0.02 (1.04)	0.02 (0.83)	0.02 (0.83)	−0.02 (1.23)	−0.02 (0.92)	0.02 (0.85)
LN(C3)	−0.10 (−0.46)	−0.15 (−0.72)	−0.18 (−0.85)	−0.18 (−0.84)	−0.09 (−0.42)	−0.10 (−0.47)	−0.17 (−0.81)
Ln(SIZE)	0.05 (0.79)	0.01 (0.15)	0.01 (−0.23)	−0.02 (−0.30)	−0.01 (−0.08)	0.02 (0.30)	−0.01 (−0.17)
Ln(CAP)	0.03 (0.80)	0.01 (0.13)	0.03 (0.95)	0.03 (0.94)	0.01 (0.04)	−0.03 (0.62)	−0.047 (0.35)
Ln(ROA)	0.02 (1.28)	*0.02* (*1.72*)***	*0.04* (*1.87*)***	*0.03* (*2.02*)**	0.02 (1.62)	0.02 (1.50)	0.03 (1.03)
Ln(LLP/TL)	−0.02 (−1.47)	*−0.02* (*1.84*)***	*−0.02* (*−1.68*)***	*−0.02* (*−1.80*)***	*−0.02* (*−1.93*)**	*−0.02* (*−1.78*)***	0.02 (1.64)***
Ln(NII/TA)	*0.10* (*5.14*)*	*0.10* (*4.91*)*	*0.09* (*4.57*)*	*0.09* (*4.59*)*	*0.16* (*6.35*)*	*0.11* (*5.33*)*	*0.09* (*4.63*)*
Ln(TL/TA)	*0.12* (*4.17*)*	*0.12* (*3.92*)**	*0.11* (*3.77*)*	*0.11* (*3.83*)*	*0.08* (*2.01*)**	*0.15* (*4.72*)*	*0.11* (*3.73*)*
Ln(LIQ)	*0.17* (*3.91*)*	*0.15* (*3.461*)*	*0.16* (*3.69*)*	*0.16* (*3.69*) *	*0.12* (*4.07*)*	*0.19* (*4.62*)*	*0.37* (*5.56*)*
IB × LnSIZE	*−0.16* (*−2.56*)*						
IB × LnCAP		*0.15* (*1.84*)***					
IB × LnROA			−0.02 (−0.62)				
IB × LnLLp/TL				0.02 (0.74)			
IB × LnNII					*−0.17* (*−4.39*)*		
IB × LnTL						*−0.13* (*3.03*)*	
IB × Ln(LIQ)							−0.02 (−0.21)
Overall R^2	0.01	0.09	0.13	0.13	0.09	0.01	0.13
Within R^2	0.15	0.14	0.13	0.13	0.17	0.15	0.13
Between R^2	0.01	0.23	0.27	0.29	0.17	0.01	0.28

Notes: The number in parentheses are the standard errors. GDP is the macroeconomic measure of the soundness of economy; INF measures the price index; C3 refers to the concentration index; size is measured by total assets; CAP is the total equity to total assets; ROA measures the profitability; LLP/TL represents the credit risk; NII/TA measures the non-interest/ finance income; TL measures the intensity of loans/ finance provided to customers; LN(LIQ) refers to liquidity risks. *,**,***Significant at 1, 5 and 10 per cent level, respectively

Similarly, capitalisation effect is confined to Islamic banks, where the findings indicate that capitalisation becomes a positive and significant influential factor only when the Islamic banks is controlled for. This result differs from the conclusion produced in Table VIII, where it shows that capitalisation has no impact. It seems that the banking model could explain some variation in the results across the models.

With respect to the interaction effect of profitability, the results suggest that profitability matters for the SE of conventional banks only. As compared to the baseline model in Table VIII, the overall indicator shows that positive relationship exists between ROA and SE. However, when the banking model is controlled for, the Islamic banks behave differently and profitability of Islamic banks is negative, although it is not significant to the SE of the Islamic banks. As in the baseline model of Table VIII, the higher the profitability, the higher the SE enabling banks to attack more deposits and then enlarging the profit and efficiency (Sufian and Habibullah, 2010). The surprise is that controlling for Islamic banks leads to a reverse relationship, although significant, it could relate to marketing strategies that the Islamic banks tend to focus on long-term objectives, which prompt them to trade off short-term profit for long-term gains (Shawtari *et al.*, 2015a).

NII/NFI is another interesting finding. The result indicates that NII/NFI is positively related to SE as shown in Table VIII's baseline mode. Nonetheless, when we control for Islamic banks, the results reverse their sign and become significantly and negatively related to SE. This result is supported by early results that profitability of Islamic banks is negatively related to SE. In a similar vein, the total loans/finance shows that total finance is related negatively to SE for Islamic banks only. Liquidity interaction with Islamic banks also shows different behaviour, where the liquidity shows non-significant effects on the SE of Islamic banks, which is different from the baseline regression that indicates that liquidity is positively related to SE. Overall, the results indicate that the Islamic banks and conventional banks are different in their behaviour with regards to the reaction of each variable to the efficiency types. This by right reflects the stature and the underlying behaviour of each banking model.

5. Conclusion and policy implications

Yemen has undergone several changes in the lasts 25 years. Its economy has passed through very slow development due to various factors. The banking industry as one of the players in the financial system faced several challenges that impeded reasonable progress, of which are institutional and regulatory factors. Although the government has attempted to transform their financial system into an efficient industry, the incentives require review to determine their efficacy. This paper examines the efficiency of the banking industry in depth by decomposing them into PTE and SE. Overall, the results provide evidence that efficiency score is low for PTE that is related to input wastage. However, the SE score is relatively higher than PTE.

Putting the results together, the Islamic banks have outperformed conventional banks in terms of their scale and total TE. However, they lag behind in terms of PTE. Therefore, we can imply that the incentives that the government have put in place exert more pressure on conventional banks as the competition is being intensified. This is an indication that Islamic banks are a significant step to improve and enhance the financial system of the country. However, there is room for further improvement in order for the industry to be the backbone of the financial system and the economy as a whole. Various initiatives requiring refinement include the informational, contractual and enforcement infrastructure in the country.

We further attempt to find the factors that influence the efficiency types of Yemen's banking sector so as to provide insight to the bankers to improve the efficiency of banks. The results of regression show that Islamic banks outperformed conventional banks in terms of SE but not in terms of PTE. The findings also indicate that the efficiencies types of the banking sector are affected by different influences. However, the behaviour of Islamic

and conventional banks are not the same, which supports the different underlying principles of Islamic and conventional banks.

To sum up, the findings suggest several implications for policy makers and bankers to take steps to improve efficiency. First, despite the fact that Islamic banks outperform conventional banks, the industry still lags behind in terms of their efficiency scores. Intensifying competition could lead to better efficiency. Furthermore, banks need to invest their resources, capabilities and introduce know-how technology that would lead to better efficiency. Bankers need to focus their efforts on improving their PTE, rather than SE. Pure technical inefficiency is directly under the control of banks and management are charged with its reduction. They have to find ways to improve their PTE via reduced operating expenses and improved staff quality based on sound screening during effective on job procurement and training activities.

This is more important for Islamic banks whose PTE pales in comparison with conventional banks. Perhaps, the Islamic banks may examine the managerial side of Islamic banks for ideas on how PTE could be improved. However, if their managerial ability shows no difference, they may look at other areas, including the remuneration system.

Second, the policy makers should take serious steps to allow for the entry of foreign banks by relaxing restrictions. This might improve competition and hence the overall efficiency of the banking industry.

This study is not without limitations. However, despite these limitations, considerable effort was exerted in conducting the study to ensure that the objectives of the study were met. The first and foremost limitation is the small sample, but that is unavoidable because of data constraints and the fact that the study is comparative in nature and the first Islamic bank in Yemen emerged only in 1996. The sample is confined to the Yemeni banking industry. Future research may extend the sample by comparing the Yemeni banking industry with others in the region and simultaneously use dynamic panel data techniques, namely GMM, instead of static panel data techniques which help to account for endogeneity problems. Second, the investigation of the study focuses on banks-specific and macroeconomic variables. Future studies are needed to go beyond this and look at other influencing factors such as informational, regulatory and institutional determinants.

Notes

1. As the nature of operation for Islamic is different from conventional banks as Islamic banks are not allowed to deal with interest, the paper uses the term finance, finance income and non-finance income as inputs to be equivalent with conventional banks inputs, namely loans, interest income and non-interest income.
2. Table AI provides details on the pure technical efficiency throughout all windows for a sample bank. Data for the remaining banks are available on request.
3. Since the regression model contains dummy variable "Islamic Bank Dummy", which is fixed, it will be perfectly correlated with bank-specific effects. Accordingly, fixed effects cannot be employed, and the random effects are used against the pooled OLS.
4. According to Hoechle (2007), the Roger standard errors are heteroscedasticity and autocorrelation consistent whenever the panel identifier (e.g. individuals, firms or countries) is the cluster variable.

References

Abbas, M., Azid, T. and Hj Besar, M.H.A. (2016), "Efficiency, effectiveness and performance profile of Islamic and conventional banks in Pakistan", *Humanomics*, Vol. 32 No. 1, pp. 2-18.

Ahmad, S. and Abdul Rahman, A.R. (2012), "The efficiency of Islamic and conventional commercial banks in Malaysia", *International Journal of Islamic and Middle Eastern Finance and Management*, Vol. 5 No. 3, pp. 241-263.

Ahmed Mokhtar, H.S.A., Abdullah, N. and Alhabshi, S.M. (2008), "Efficiency and competition of Islamic banking in Malaysia", *Humanomics*, Vol. 24 No. 1, pp. 28-48.

Ajlouni, M.M., Hmedat, M.W. and Hmedat, W. (2011), "The Relative efficiency of Jordanian banks and its determinants using data envelopment analysis", *Journal of Applied Finance and Banking*, Vol. 1 No. 3, pp. 33-58.

Akhigbe, A. and McNulty, J.E. (2003), "The profit efficiency of small US commercial banks", *Journal of Banking & Finance*, Vol. 27 No. 2, pp. 307-325.

Al-Gasaymeh, A. (2016), "Bank efficiency determinant: evidence from the gulf cooperation council countries", *Research in International Business and Finance*, Vol. 38, pp. 214-223.

Asteriou, D. and Hall, S.G. (2007), *Applied Econometrics: A Modern Approach Using Eviews and Microfit Revised Edition*, Palgrave Macmillan.

Avkiran, N.K. (2004), "Decompositng technical efficiency and window analysis", *Studies in Economic and Finance*, Vol. 22 No. 1, pp. 61-91.

Banker, R. (1993), "Maximum likelihood, consistency, and data envolvment analysis: a statistical foundation", *Managment Science*, Vol. 30 No. 10, pp. 1265-1273.

Banker, R. and Natarajan, R. (2004), "Productivity change, technical change, technical progress, relative efficiency change in the public accounting industry", *Managment Science*, Vol. 51 No. 2, pp. 291-304.

Banker, R. and Natarajan, R. (2008), "Evaluating contextual variables affecting producitivty using data envolvment analysis", *Operation Research*, Vol. 56 No. 1, pp. 48-58.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984), "Model for estimating technical and scale efficiencies in data envolvment anlaysis", *Science*, Vol. 30 No. 9, pp. 1078-1092.

Barro, R.J. (1995), "Inflation and economic growth", Working Paper No. 5326, National Bureau of Economic Research.

Ben Naceur, B.S. and Ghazouani, S. (2005), "Does inflation impact on financial sector performance in the MENA region?", *Review of Middle East Economics and Finance*, Vol. 3 No. 3, pp. 219-229.

Berger, A.N., Handcock, D. and Humphery, D. (1993), "Bank efficiecny derived from the profit function", *Journal of Banking and Finance*, Vol. 17 Nos 2/3, pp. 332-345.

Boyd, J.H., Levine, R. and Smith, B.D. (2001), "The impact of inflation on financial sector performance", *Journal of Monetary Economics*, Vol. 47 No. 2, pp. 221-248.

Breusch, T.S. and Pagan, A.R. (1980), "The Lagrange multiplier test and its applications to model specification in econometrics", *The Review of Economic Studies*, Vol. 47 No. 1, pp. 239-253.

Canhoto, A. and Dermine, J. (2003), "A note on banking efficiency in Portugal: new vs old bank", *Journal of Banking and Finance*, Vol. 27 No. 11, pp. 2087-2098.

Campisi, D. and Costa, R. (2008), "A DEA-based method to enhance intellectual capital management", *Knowledge and Process Management*, Vol. 15 No. 3, pp. 170-183.

Charnes, A., Clark, C.T., Cooper, W.W. and Golany, B. (1985), "A developmental study of data development analysis in measuring the efficiency of maintenance units in the US Air Forces", *Annals of Operations Research*, Vol. 2 No. 1, pp. 95-112.

Chortareas, G.E., Girardone, C. and Ventouri, A. (2012), "Bank supervision, regulation, and efficiency: evidence from the European Union", *Journal of Financial Stability*, Vol. 8 No. 4, pp. 292-302.

Chortareas, G.E., Girardone, C. and Ventouri, A. (2013), "Financial freedom and bank efficiency: evidence from the European Union", *Journal of Banking & Finance*, Vol. 37 No. 4, pp. 1223-1231.

Danijela, P., Aleksandar, R., Zlatko, H. and Vladeta, C. (2012), "DEA window analysis for measuring port efficiencies In Serbia", *Traffic Managment*, Vol. 24 No. 1, pp. 63-72.

Donkor, J. and Kodua, K. (2013), "Profitability, liquidity and efficiency of rural banks: evidence from Ghana", *British Journal of Economics, Finance and Management Sciences*, Vol. 8 No. 1, pp. 1-11.

Drake, L. (2001), "Efficiency and productivity change in UK banking", *Applied Financial Economics*, Vol. 11 No. 5, pp. 557-571.

Fiordelisi, F., Marques-Ibanez, D. and Molyneux, P. (2011), "Efficiency and risk in European banking", *Journal of Banking & Finance*, Vol. 35 No. 5, pp. 1315-1326.

Gunes, N. and Yilmaz, A. (2016), "Determinants of the efficiencies in Turkish banking sector (Tobit Analysis)", *International Journal of Economics and Finance*, Vol. 8 No. 2, pp. 215-225.

Halkos, G.E. and Tzeremes, N. (2009), "Exploring the existance of kuznets curve in countries environmental efficiency using DEA window analysis", *Ecological Economics*, Vol. 68 No. 7, pp. 2168-2176.

Hassan, T., Mohamad, S and Bader, M.K.I. (2009), "Efficiency of conventional versus Islamic banks: evidence from the Middle East", *International Journal of Islamic and Middle Eastern Finance and Management*, Vol. 2 No. 1, pp. 46-65.

Hausman, J.A. (1978), "Specification tests in econometrics", *Econometrica: Journal of the Econometric Society*, pp. 1251-1271.

Hoechle, D. (2007), "Robust standard errors for panel regressions with cross-sectional dependence", *Stata Journal*, Vol. 7 No. 3, p. 281.

Hsiao, C. (2003), *Analysis of Panel Data*, Cambridge University Press, Cambridge.

Huang, Y., Mesak, H., Hsu, M. and Qu, H. (2012), "Dynamic efficiency assessment of the chinese hotel industry", *Journal of Business Research*, Vol. 65 No. 1, pp. 59-67.

Isik, I. and Hassan, M.K. (2002), "Technical, scale, and allocative efficiencies of Turkish banking industry", *Journal of Banking and Finance*, Vol. 26 No. 4, pp. 719-766.

Isik, I. and Hassan, M.K. (2003), "Financial deregulation and total factor productivity change: an empirical study of Turkish commercial banks", *Journal of Banking & Finance*, Vol. 27 No. 8, pp. 1455-1485.

Johnes, J., Izzeldin, M. and Pappas, V. (2013), "A comparison of performance of Islamic and conventional banks 2004-2009", *Journal of Economic Behavior & Organiation*, Vol. 103, pp. 2-15.

Kisielewska, M., Guzowska, M., Nellis, J. and Zarsecki, D. (2005), "Polsih banking industry efficiency: DEA window anlaysis approach", *International Journal of Banking and Finance*, Vol. 3 No. 1, pp. 15-31.

Kumar, S. and Gulati, R. (2009), "Measuring efficiency, effectiveness and performance of Indian public sector banks", *International Journal of Productivity and Performance Management*, Vol. 59 No. 1, pp. 51-74.

McDonald, J. (2009), "Using least square and tobit in second stage DEA efficiency anlayses", *European Journal of Operational Research*, Vol. 197 No. 2, pp. 792-798.

Majeed, M.T. and Zanib, A. (2016), "Efficiency analysis of Islamic banks in Pakistan", *Humanomics*, Vol. 32 No. 1, pp. 19-32.

Miller, S.M. and Noulas, A.G. (1997), "Portfolio mix and large-bank profitability in the USA", *Applied Economics*, Vol. 29 No. 4, pp. 505-512.

Pasiouras, F. and Kosmidou, K. (2007), "Factors influencing the profitability of domestic and foreign commercial banks in the European Union", *Research in International Business and Finance*, Vol. 21 No. 2, pp. 222-237.

Piyu, Y. (1992), "Data envelopment analysis and commercial bank performance: a primer with applications to Missouri banks", *Federal Reserve Bank of St. Louis Review*, Vol. 74 No. 1, pp. 31-45.

Poghosyan, T. (2013), "Financial intermediation costs in low income countries: the role of regulatory, institutional, and macroeconomic factors", *Economic Systems*, Vol. 37 No. 1, pp. 92-110.

Raab, R.L. and Lichty, R.W. (2002), "Identifying subareas that comprise a greater metropolitan area: the criterion of county relative efficiency", *Journal of Regional Science*, Vol. 42 No. 3, pp. 579-594.

Rashid, A. and Jabeen, S. (2016), "Analyzing performance determinants: conventional versus Islamic banks in Pakistan", *Borsa Istanbul Review*, Vol. 16 No. 2, pp. 92-107.

Reisman, A., Daouas, M., Oral, M., Rebai, S. and Gatoufi, S. (2003), "Impact of deregulation on technical and scale efficiencies of Tunisian commercial banks: window extended data envelopment analysis", working paper, Faculte des Sciences Economiques et de Gestion de Tunis, Universite El Manar.

Řepková, I. (2014), "Efficiency of the Czech banking sector employing the DEA window analysis approach", *Procedia Economics and Finance*, Vol. 12, pp. 587-596.

Rogers, W.H. (1993), "Regression standard errors in clustered samples", Stata Technical Bulletin 13, pp. 19–23. In Stata Technical Bulletin Reprints, Vol. 3, Stata Press, College Station, TX, pp. 88-94.

Sahoo, B.K. (2016), "Ownership, size, and efficiency: evidence from software companies in India", *Benchmarking: An International Journal*, Vol. 23 No. 2, pp. 313-328.

Said, A. (2012), "Comparing the change in efficiency of the Western and Islamic banking systems", *Journal of Money, Investment and Banking*, Vol. 23 No. 1, pp. 149-180.

Sathye, M. (2001), "X-Efficiency in Australian banking: an emprical investigation", *Journal of Banking and Finance*, Vol. 25 No. 3, pp. 613-630.

Saxena, P., Saxena, R.R. and Sehgal, D. (2016), "Efficiency evaluation of the energy companies in CNX 500 Index of the NSE, India using data envelopment analysis", *Benchmarking: An International Journal*, Vol. 23 No. 1, pp. 113-126.

Seiford, L.M. and Thrall, R.M. (1990), "Recent developments in DEA: the mathematical programming approach to frontier analysis", *Journal of Econometrics*, Vol. 46 Nos 1-2, pp. 7-38.

Shawtari, F.A., Ariff, M. and Abdul Razaq, S.H. (2014), "Efficiency and Stability assessment of the Yemeni Banking sector using Data Envelopment Windows Analysis (DEWA) in recent developments in data envelopment analysis and its applications", in Emrouznejad, A., Banker, R., Doraisamy, S.M. and Arabi, B. (Eds), *Proceedings of the 12th International Conference of DEA*, Kuala Lumpur, pp. 144.-153.

Shawtari, F.A., Ariff, M. and Abdul Razak, S.H. (2015a), "Efficiency assessment of banking sector in Yemen using data envelopment window analysis: a comparative analysis of Islamic and conventional banks", *Benchmarking: An International Journal*, Vol. 22 No. 6, pp. 1115-1140.

Shawtari, F.A., Saiti, B., Razak, S.H.A. and Ariff, M. (2015b), "The impact of efficiency on discretionary loans/finance loss provision: a comparative study of Islamic and conventional banks", *Borsa Istanbul Review*, Vol. 15 No. 4, pp. 272-282.

Shawtari, F.A., Ariff, M. and Abdul Razak, S.H. (2018), "Efficiency and bank margins: a comparative analysis of Islamic and conventional banks in Yemen", *Journal of Islamic Accounting and Business Research*, Vol. 9 No. 5, (forthcoming).

Singh, G., Singh, P. and Munisamy, S. (2008), "A cross country comparison of banking efficiency: Asia Pacific banks", *International Review of Business Research Papers*, Vol. 4 No. 3, pp. 73-95.

Staub, R.B., e Souza, G.D.S. and Tabak, B.M. (2010), "Evolution of bank efficiency in Brazil: a DEA approach", *European Journal of Operational Research*, Vol. 202 No. 1, pp. 204-213.

Sufian, F. (2007), "Trends in the efficiency of Singapore's commercial banking groups: a non-stochastic frontier DEA window analysis approach", *International Journal of Productivity and Performance Management*, Vol. 56 No. 2, pp. 99-136.

Sufian, F. (2009), "Determinants of bank efficiency during unstable marcroeconomic environment: emprical evidence from Malaysia", *Research in International Business and Finance*, Vol. 23 Nos 54/77.

Sufian, F. (2011), "Benchmarking the efficiency of the Korean banking sector: a DEA approach", *Benchmarking: An International Journal*, Vol. 18 No. 1, pp. 107-127.

Sufian, F. and Habibullah, M. (2010), "Development in the efficiency of the Thailand banking sector: a DEA Approach", *International Journal of Development Issues*, Vol. 9 No. 3, pp. 226-245.

Sufian, F. and Kamarudin, F. (2016), "Determinants of efficiency in the Malaysian banking sector: does bank origins matter?", *Intellectual Economics*, Vol. 10 No. 1, pp. 38-54.

Sufian, F. and Majid, M.Z.A. (2009), "Bank efficiency and share prices in China: empirical evidence from a three-stage banking model", *International Journal of Computational Economics and Econometrics*, Vol. 1 No. 1, pp. 23-47.

Tecles, P.L. and Tabak, B.M. (2010), "Determinants of bank efficiency: the case of Brazil", *European Journal of Operational Research*, Vol. 207 No. 3, pp. 1587-1598.

Tsionas, E.G., Assaf, A.G. and Matousek, R. (2015), "Dynamic technical and allocative efficiencies in European banking", *Journal of Banking and Finance*, Vol. 52, pp. 130-139.

Walker, G. (1998), "Economies of Scale in Australian Banks 1978-1990", *Australian Economic Papers*, Vol. 37, pp. 71-87.

Webb, R. (2003), "Level of efficiency in UK retial banks: a DEA window analysis", *International Journal of the Economics of Business*, Vol. 10 No. 3, pp. 305-322.

White, H. (1980), "A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity", *Econometrica: Journal of the Econometric Society*, pp. 817-838.

Wooldridge, J.M. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press, Cambridge, MA.

Zimkova, E. (2014), "Technical efficiency and super efficiency of the banking sector in Slovakia", *Procedia Economics and Finance*, Vol. 12, pp. 780-787.

Further reading

Asmild, M., Paradi, J.C., Aggrawall, V. and Shaffnit, C. (2004), "Combining DEA window analysis with the malmquist index approach in a study of the Canadian banking industry", *Journal of Productivity Analysis*, Vol. 21 No. 1, pp. 67-89.

Berger, A.N. and Humpery, D.B. (1997), "Efficiency of financial intuitions: international survey and directions for future research", *European Journal of Operatioanal Research*, Vol. 98 No. 2, pp. 175-212.

Berger, A.N. and Mester, L. (1997), "Inside the black box: what explains differences in the efficiencies of financial institutions?", *Journal of Banking and Finance*, Vol. 21, pp. 895-947.

Bulak, M.E., Turkyilmaz, A., Satir, M., Shoaib, M. and Shahbaz, M. (2016), "Measuring the performance efficiency of Turkish electrical machinery manufacturing SMEs with frontier method", *Benchmarking: An International Journal*, Vol. 23 No. 7, pp. 2004-2026.

Coelli, T., Prasada-Roa, D. and Battese, G. (1998), *An Introduction to Efficinecy and Productivity Analysis*, Kluwer Academic, Boston, MA.

Galab, N. (2006), "The impact of liberalisation on the efficiency of banking sector in Yemen", unpublished PhD Thesis, Arab Academy for Banking and Financial Sceinces, Amman.

Grabowski, R., Rangan, N. and Rezvanian, R. (1994), "The effect of dergulation on the efficiency of US banking firms", *Journal of Economic and Business*, Vol. 46, pp. 39-54.

Mahathanaseth, I. and Tauer, W. (2012), "Market-power versus cost-efficiency in Thailand's banking sector in the post-crisis period (1998–2011)", *Journal of Asian Economics*, Vol. 23 No. 5, pp. 499-506.

Mirzaei, A., Moore, T. and Liu, G. (2013), "Does market structure matter on banks' profitability and stability? Emerging vs advanced economies", *Journal of Bnaking and Finance*, Vol. 37 No. 8, pp. 2920-2937.

Mostafa, M. (2007), "Modelling the efficiency of GCC banks: a data envelopment analysis approach", *International Journal of Productivity and Performance Management*, Vol. 56 No. 7, pp. 623-643.

Neal, P. (2004), "X-efficiency and productivity change in Australian banks", *Australian Economic Papers*, Vol. 43 No. 2, pp. 174-191.

Omar, M., Majid, M. and Rulindo, R. (2007), "Efficiency and productivity performance of the national private banks in Indonesia", *International Journal of Business*, Vol. 9 No. 1, pp. 1-18.

Rayeni, M.M. (2012), "A study on benchmarking based on window analysis", *International Journal of Business and Managment Tomorrow*, Vol. 2 No. 4, pp. 1-7.

Rosman, R., Wahab, N.A. and Zainol, Z. (2014), "Efficiency of Islamic banks during the financial crisis: an analysis of Middle Eastern and Asian countries", *Pacific-Basin Finance Journal*, Vol. 28, pp. 76-90.

Safrali, A. and Gumus, K. (2010), "The effect of macroeconomic factors on the performance of Azerbaijan banking system", *Journal of Money, Investment and Banking*, Vol. 1 No. 25, pp. 59-69.

Sherman, H.D. and Gold, F. (1985), "Bank branch operating efficiency, evaluation with data envelopment analysis", *Journal of Banking and Finance*, Vol. 9 No. 2, pp. 297-315.

Wozniewska, G. (2008), "Methods of measuring the efficiency of commercial banks: an example of Polish banks", *Ekonomika*, Vol. 85, pp. 81-91.

Corresponding author
Fekri Ali Shawtari can be contacted at: fekri.shawtari@ccq.edu.qa

Appendix

Bank	Window	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011		Mean/ W	Mean	SD
National Bank of Yemen	1	0.41	0.34	0.19															0.31		
	2		0.32	0.18	0.72														0.41		
	3			0.70	1.00	0.10													0.60		
	4				1.00	0.12	0.15												0.42	0.48	0.16
	5					0.15	0.18	0.35											0.23		
	6						0.18	0.33	0.36										0.29		
	7							0.30	0.33	0.40									0.34		
	8								0.30	0.36	0.41								0.36		
	9									0.36	0.39	0.87							0.54		
	10										0.39	0.66	1.00						0.68		
	11											0.58	0.91	0.67					0.72		
	12												0.94	0.70	0.49				0.71		
	13													0.57	0.42	0.50			0.50		
	14														0.32	0.35	1.00		0.56		
	Mean/Year	0.41	0.33	0.36	0.91	0.12	0.17	0.33	0.33	0.40	0.70	0.70	0.95	0.65	0.41	0.42	1.00		0.51		
	Mean Windows 1–7																	0.37			
	Mean Windows 8–14																	0.62			

Table AI. Pure technical efficiency