The Use of Data Envelopment Analysis in Measuring the Performance Efficiency – Evidence from Bahrain

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Abstract - This study uses two models of the data envelopment analysis (DEA) to measure the performance efficiency of a sample of listed Bahraini banking and investment firms. The first model (CCR Model) which introduced by Charnes, Cooper and Rhodes (1978) was used to measure the overall technical efficiency; while to measure pure technical efficiency and scale efficiency as two components of the overall technical efficiency, the second model (BCC Model) introduced by Banker, Charnes and Cooper's model - BCC (1984) was applied. Although the use of two different models to measure performance efficiency led to different results, each model has its own characteristics and uses. Therefore, the decision maker must determine his/her needs before selecting a model to be used in the measurement of corporate performance efficiency. The main finding indicates that different models provided different results over the 2013-17 period.

Keywords - Efficiency Performance, Data Envelopment Analysis, Banking and Investment Sector.

I. INTRODUCTION

In our modern world, with the sharp competition between companies and the desire of each company to achieve more profits, attract more customers and control of the market, the issue of measuring the performance efficiency characterized by having privileged position and attracts the attention of decision-makers in different fields of business. Beccalli et al. (2006, p.245) point out "when a firm uses less inputs for the same level of outputs or profit maximising by producing more outputs for the same amount of inputs, this reflects operating efficiency of the firm". In the light of the fact of the scarcity of resources, the efficient use of resources is important not only for business organizations but also for the whole society. In general, banking and investment sectors play a strong role in economic growth of countries. Thus, the efficient use of resources in these sectors is an urgent issue to achieve economic growth and prosperity (Bushman, 2014). The present study measures the efficiency of performance in a sample of banking and investment listed firms on Bahrain Bourse (BHB) which accounted for 48.35% and 26.08% of the total market capitalization of BHB respectively (BHB, 2017, p. 22). The data envelopment analysis (DEA) has a number of characteristics distinguishing it from other traditional methods such as ratios of financial analysis. For example, DEA can use multiple inputs and outputs. Moreover, it does not require to assign weights to the various inputs and outputs or to identify priori assumptions. Consequently, DEA can provide a comprehensive assessment of corporate performance especially in a complex and highly competitive banking environment (El-Mashaleh et al. 2010; Zhu, 2014). Several studies have presented different advantages for the DEA technique (Ray, 2004; Halkos and Salamouris, 2004, Mousa, 2015). Several studies applied DEA approach in different countries with a variety of business. For example, Zen and Baldan (2008) assessed the efficiency of an Italian group of Mutual Banks using DEA. In Pakistan, Akhtar et al. (2011) conducted DEA to evaluate the relative performance efficiency of twelve financial institutions (commercial banks). In Turkey, Isik and Hassan (2003) investigated different factors that affect the efficiency of banks and reported that foreign banks are more efficient than private domestic banks. In Jordan, El-Mashaleh et al. (2010) adopted the DEA to assess the efficiency of 45 construction firms. The current study will provid empirical evidence on the performance efficiency of listed firm in BSB representing two sectors, banking and investment. The results of the study can help decision makers in these two important sectors. The structure of the current study is as follows: Section 2 presents the related literature. Section 3 provides the research methods. Section 4 shows results and analysis. Finally, the study's conclusions are introduced in Section 5.

II. LITERATURE REVIEW

The literature on measuring the efficiency of corporate performance offered several studies with different approaches and conflicting results. For example, Khajavi et al. (2010) used DEA to measure the efficiency of a sample of companies in Nigeria and found that 32 firms out of a total of 267 firms are efficient. Another study in the same country conducted by Eriki and Osifo (2015) who identified factors affecting the efficiency of 19 banks. Using a

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sample of listed banks in a number of countries including Italy, Germany, France, Spain and United Kingdom, Beccalli et al (2006) studied the association between the bank efficiency and stock prices from 1999 to 2000. The authors concluded that DEA has a higher explanatory power than traditional financial ratios. Moreover, the results showed that efficient banks are more profitable and have a lower cost of capital than inefficient banks. In a comprehensive study that includes 715 banks from 95 countries, Pasiouras (2008) used the DEA technique to study the effect of regulation on banks' efficiency and concluded that it plays a critical role to improve banks' efficiency. Mousa (2015) investigated the efficiency of corporate firms using a sample of Bahraini firms from (2009-2013) and found that there are 12 out of 20 firms are efficient in 2013 and 2012, while there are 11 firms in 2010 and 10 firms in 2009 are efficient. In Greece, Halkos and Salamouris (2004) analysed the efficiency of performance of Greek banks using DEA models and reported that the higher the size of total assets the higher the efficiency of performance. Feroz et al. (2008) analysed corporate behaviour to recognize the validity of DEA rankings for the sample of pharmaceutical firms and found that the DEA efficiency of performance rankings are affected by the strategic selections made by the key management. In Malaysia, many studies have been conducted using DEA. For instance, Tahir and Yusof (2011) estimated the technical and scale efficiency for 14 public listed firms using 2 inputs and 1 output. The reported results showed that only 1 out of 14 firms is relatively efficient.

III. RESEARCH METHODS

The current research measures the performance efficiency of two groups of listed banks and investment firms in BHB during a period of five years (2013-2017) using the DEA approach which offers a complete analysis of the relative efficiency for multiple input-multiple output situations through the evaluation of each sampled firm as a decision-making unit (DMU) and the measurement of its performance relative to this envelopment surface. "Units that lie on (determine) the surface is deemed efficient in the DEA terminology. Units that do not lie on the surface are termed inefficient and the analysis provides a measure of their relative efficiency" (El-Mashaleh et al. 2010, p. 64). In adopting the DEA, each firm of the sample is assigned a score of efficiency ranging from 0 to 1. An efficiency score of < 1 is generally supposed to be inefficient. Charnes, Cooper and Rhodes (1978) introduced first model of the DEA (CCR Model) to determine the involved technical details. This Model (CCR Model) was employed for measuring the overall technical efficiency through the measurement of the constant return to scale model (CRS). The second model of DEA which presented by Banker, Charnes and Cooper (BCC Model) in (1984) focusses on the usage of variable returns to scale the VRS which decomposes over technical efficiency into a product of two components namely scale efficiency and pure technical efficiency. The Pure technical efficiency refers to managers' capability to use firms' available resources, whereas the scale efficiency, refers to exploiting scale economies by operating at a point where the production frontier exhibits CRS. Furthermore, two approaches of DEA are available, input-oriented approach (IOA) or output-oriented approach (OOA).

According to Coelli et al. (2005), measures of the first approach (IOA approach) address the following question: "By how much can input quantities be proportionally reduced without changing the output quantities produced?" (p. 137). However, measures of the second approach (OOA approach) address another question stating: "by how much can output quantities be proportionally expanded without altering the input quantities used?" (p. 137). A full argument on DEA is provided by several previous studies including Farrell (1957); Fare (1985); Coelli (1994 & 2005); Seiford (1996); and Cooper (2000).

A. DEA approach

Following Mousa (2015) this study used both models of the DEA (CCR – BCC Models) for measuring CRS and VRS of the sampled firms. The DEA results of the current study are obtained by using a software that is DEAP 2.1 version introduced by Coelli (1996).

First: measuring the constant return to scale model (CRS)

According to this analysis, it is possible to calculate the ratio of CRS to VRS efficiency to obtain a measure of scale efficiency. If resulted ratio is = 1, then a firm is scale efficient; however, if the resulted ratio is < one, the DUM is scale inefficient. The related mathematical programming of the model is presented by Coelli (1996, p. 11) as "the objective function is:

$$\max_{u,v}(\acute{u}y_i/\acute{v}x_i)$$

Subject to

$$\frac{\acute{u}y_j}{\acute{v}x_j} \leq 1, \quad j = 1,2,\dots,N$$

and

$$u, v \geq 0$$

Where y_i are outputs and x_i are inputs and this involves finding values for u and v such that the efficiency measure for the i-th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one". Coelli (1996, p. 11) stated that "one problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this, it can be imposed the constraint $\acute{v}x_i = 1$, which provides:

$$\max_{u,v}(\acute{u}y_i)$$

Subject to

$$\acute{v}x_i = 1$$

$\acute{u}y_j - \acute{v}x_j \leq 0, \quad j = 1,2,\ldots..N$
$u, v \geq 0$

Using the duality in linear programming on can derive an equivalent envelopment for this problem as

$$\min_{\theta,\lambda}\theta$$

Subject to
$-y_i + Y\lambda \geq 0,$
$\theta x_i - X\lambda \geq 0$
$\lambda \geq 0$

Where θ is a scalar and λ is a vector of constants."

Second: measuring the variable returns to scale model (VRS)

"The linear programming problem of CRS could be modified to account for the VRS. This suggested model is presented by Coelli (1996, p. 16) as

The objective function is

$$\min_{\theta,\lambda}\theta$$

Subject to
$-y_i + Y\lambda \geq 0,$
$\theta x_i - X\lambda \geq 0$
$N1\lambda = 1$
$\lambda \geq 0$

Where $N1$ is vector of ones. This approach provides technical efficiency scores which are greater than or equal to those obtained using the CRS model." For more details; see also, Norman and Stoker (1991) and Lovell (1994).

B. The selection of inputs and outputs

Studies on measuring firm performance efficiency depend heavily on the selection of variables and the determination of inputs and outputs. As the economic activities are different in their nature and degree of complexity in their operations, the accounting literature includes several studies that used different types of outputs and inputs and provided different results. Considering prior literature (Akhtar et al, 2011; Tahir and Yusof, 2011; Titko and Jureviciene, 2014; Eriki and Osifo, 2015 and Mousa 2015), four inputs and three outputs are used in the current study. These inputs and outputs were suggested by Mouse (2015, p. 13). Table (1) below presents the inputs and outputs definitions.

Table (1) Definitions of inputs and outputs

Variable	Definition
Inputs	
1. Total oper. expenses (X1)	1. The end of year total oper. expenses.
2. Total general & admin. expenses (X2)	2. The year-end total general and admin. expenses.
3. Total liabilities (X3)	3. The end of year total liabilities.
4. Equity capital (X4)	4. The end of year total owners' equity.
Outputs	
1. Total oper. income (Y1)	1. The end of year total oper. income.
2. Reserves (Y2)	2. The end of year total reserves.
3.Investments (Y3)	3. Profits earned from the investment portfolio

Adapted from: Mousa (2015, p.13)

C. Data collection and sample size

Our final sample includes 17 listed banks and investment firms in BHB. after excluding Three Islamic banks were excluded from banking sector because of their special characteristics. Data collected from 85 annual reports of the sampled firms covering the period from 2013 to 2017. A list of the sampled firms is presented in Appendix (1).

IV. RESULTS AND ANALYSIS

DEA results in this study are obtained via a specific software that is DEAP 2.1 version. Table (2) presents efficiency scores and ranks of the sampled firms. Clearly, it shows that all firms have a level of efficiency with CRS scores ranging from 0.097 to 1.00, while VRS efficiency scores range from 0.334 to 1. Based on CRS results, 7 out of 17 firms are efficient (AUB; ABC; INOVEST; INVCORP; TAIB; UGIC; GMG); while based on VRS results, 11 out of 17 firms are efficient. Further, Table (2) shows efficiency ranking of the 17 firms included in this study.

Table (2) The efficiency scores and ranks - 2017

No.	Firms	CRS	VRS	Scale	Rank*
1	AUB	1	1	1	1
2	BBK	0.777	1	0.777	5
3	KHCB	0.575	0.575	1	1
4	NBB	0.770	0.893	0.862	4
5	BSB	0.301	0.334	0.903	3
6	BARKA	0.275	0.512	0.536	9
7	ABC	1	1	1	1
8	BCFC	0.623	1	0.623	8
9	BMB	0.671	1	0.671	7
10	ESTERAD	0.758	1	0.758	6
11	GFH	0.097	0.559	0.174	10
12	INOVEST	1	1	1	1
13	INVCORP	1	1	1	1
14	TAIB	1	1	1	1
15	UGB	0.633	0.648	0.977	2
16	UGIC	1	1	1	1
17	GMG	1	1	1	1
Mean		0.734	0.854	0.84	

*For Table 2 to Table 6, the Rank column was based on scale efficiency. All efficient firms which have 1 in the scale efficiency column taking rank 1 while other firms are ranked by descending order.

Concerning 2016, Table 3 provides DEA results on the period 2016. Clearly, of the 17 sampled firms, there are 8 efficient firms with scale efficiency based on CRS. They have shown full technical efficiency in 2016. Besides, based on VRS, the number of efficient firms is 10 out of 17 included in this study.

Table (3) The efficiency scores and ranks - 2016

No.	Firms	CRS	VRS	Scale	Rank*
1	AUB	1	1	1	1
2	BBK	0.988	1	0.988	2
3	KHCB	0.56	0.636	0.881	7
4	NBB	0.389	0.407	0.958	5
5	BSB	1	1	1	1
6	BARKA	0.316	0.766	0.412	10
7	ABC	1	1	1	1
8	BCFC	0.272	0.28	0.971	4
9	BMB	0.498	1	0.498	9
10	ESTERAD	0.509	0.547	0.929	6
11	GFH	0.598	0.708	0.844	8
12	INOVEST	1	1	1	1
13	INVCORP	1	1	1	1
14	TAIB	1	1	1	1
15	UGB	0.668	0.684	0.978	3
16	UGIC	1	1	1	1
17	GMG	1	1	1	1
Mean		0.753	0.825	0.909	

Concerning scale efficiency, the below table, Table (4) shows that 10 out of 17 firms show full technical efficiency in 2015 while 7 firms are found inefficient. Table (5) shows that 12 out of 17 firms have shown full technical efficiency on basis of CRS in 2014 while other firms are inefficient.

Table (4) The efficiency scores and ranks - 2015

No.	Firms	CRS	VRS	Scale	Rank*
1	AUB	1	1	1	1
2	BBK	0.436	0.64	0.681	5
3	KHCB	1	1	1	1
4	NBB	0.283	0.529	0.535	6
5	BSB	1	1	1	1
6	BARKA	1	1	1	1
7	ABC	0.351	0.369	0.951	3
8	BCFC	1	1	1	1
9	BMB	1	1	1	1
10	ESTERAD	1	1	1	1
11	GFH	1	1	1	1
12	INOVEST	0.169	1	0.169	8
13	INVCORP	0.995	1	0.995	2
14	TAIB	0.378	0.824	0.459	7
15	UGB	1	1	1	1
16	UGIC	1	1	1	1
17	GMG	0.413	0.492	0.839	4
Mean		0.766	0.874	0.861	

Table (5) The efficiency scores and ranks - 2014

No.	Firms	CRS	VRS	Scale	Rank*
1	AUB	0.68	1	0.68	4
2	BBK	0.451	0.456	0.988	3
3	KHCB	1	1	1	1
4	NBB	1	1	1	1
5	BSB	1	1	1	1
6	BARKA	1	1	1	1
7	ABC	1	1	1	1
8	BCFC	1	1	1	1
9	BMB	1	1	1	1
10	ESTERAD	1	1	1	1
11	GFH	0.369	1	0.369	6
12	INOVEST	1	1	1	1
13	INVCORP	0.591	1	0.591	5
14	TAIB	1	1	1	1
15	UGB	1	1	1	1
16	UGIC	0.468	0.473	0.99	2
17	GMG	1	1	1	1
Mean		0.856	0.937	0.919	

Undoubtedly, Table (6) shows that all firms have a level of efficiency with both CRS and VRS scores ranging from 0.431 to 1 and from 0.546 to 1.00 respectively. Based on CRS results, 12 out of 17 firms are efficient; while based on VRS results, 14 out of 17 firms are efficient. These results indicate that among the five years included in the current study, the year 2013 has witnessed the highest level of performance efficiency especially when based on CRS.

Table (6) The efficiency scores and ranks - 2013

No.	Firms	CRS	VRS	Scale	Rank*
1	AUB	1	1	1	1
2	BBK	1	1	1	1
3	KHCB	0.708	0.719	0.984	3
4	NBB	0.565	0.571	0.989	2
5	BSB	1	1	1	1
6	BARKA	1	1	1	1
7	ABC	0.674	1	0.674	6
8	BCFC	1	1	1	1
9	BMB	1	1	1	1
10	ESTERAD	1	1	1	1
11	GFH	1	1	1	1

12	INOVEST	0.866	1	0.866	4
13	INVCORP	1	1	1	1
14	TAIB	1	1	1	1
15	UGB	1	1	1	1
16	UGIC	1	1	1	1
17	GMG	0.431	0.546	0.79	5
Mean		0.897	0.932	0.959	

One of the unique characteristics of using DEA in measuring the performance efficiency is that it identifies the probable enhancements and developments of inefficient DMUs or firms. In the current study, if the DEA results showed that all the slacks' DMUs of inputs and outputs are equal to 0.00, therefore, DMU can be defined to be efficient (CRS, VRES or Scale). Conversely, other input and/or output slacks are not equal to zero, then the DMU can be defined to be inefficient (CRS, VRES or Scale) and there is a probability to enhance its efficiency through either minimizing its input levels or maximizing its output levels (Zhu, 2000 and Mousa, 2015). The below table, Table (7), provides inputs values (X1; X2; X3 and X4) and their related projected values. Table (7) shows that inefficient companies need improvements. For example, NBB is inefficient DUM and NBB shows an excess of the amounts of (X2; X3) by the following amounts (27225; and 24200 respectively); therefore top management of NBB to improve its performance. It needs to reduce the amounts of its inputs (X2 and X3). Similarly, BSB is recommended to reduce some of its inputs (X2 and/or X4) to realize enhancements and improve their performance to be more effective.

However, the findings of DEA revealed how inefficient DUMs can develop their performance through changing the outputs. The below table, Table (8), presents the output improvements related to inefficient DUMs for the period 2017. The table shows output slacks for each firm. For instance, NBB is inefficient with slake equal zero for Y2, while slack of Y1 equal (99750) and slack of Y3 equal (1592800). Consequently, NBB needs to enhance its Y1 by (99750) and Y3 by (1592800) to improve its efficiency level. Similarly, BARKA needs to inhance Y1 and Y2 by 7314 and 324057 respectively.

Table (7) Results for inputs of inefficient -2017

Firms	Inputs type	Original value	Slack	Projected value
BBK	X1	163432	0	163432
	X2	21546	0	21546
	X3	19152	0	19152
	X4	1080000	0	1080000
NBB	X1	253184	0	226218
	X2	284832	-27225	227271
	X3	253184	-24200	202018
	X4	576171	0	514806
BSB	X1	18640	0	6220
	X2	141084	-7190	39885
	X3	125408	0	41844
	X4	900000	-76066	224233
BARKA	X1	17096	0	8751
	X2	3240	-6178	10412
	X3	28808	0	14746
	X4	450000	-6178	124200
BCFC	X1	730640	0	730640
	X2	732384	0	732384
	X3	651008	0	651008
	X4	2137590	0	2137590
BMB	X1	1368000	0	1368000
	X2	888966	0	888966
	X3	790192	0	790192
	X4	3393000	0	3393000
ESTERAD	X1	17096	0	17096
	X2	418779	0	418779
	X3	372248	0	372248
	X4	99000	0	99000
GFH	X1	74328	-30609	10906
	X2	33156	0	18519
	X3	29472	0	16461
	X4	177579	0	99186
UGB	X1	151384	-63163	34918
	X2	91188	0	59080
	X3	81056	0	52515
	X4	363096	0	235248

Table (8) Results for outputs of inefficient - 2017

Firms	Inputs type	Original value	Slack	Projected value
BBK	Y1	73160	0	73160
	Y2	147771	0	147771
	Y3	1311384	0	1311384
NBB	Y1	842992	99750	942742
	Y2	1123866	0	123866
	Y3	3641160	1592800	5233960
BSB	Y1	104168	65084	169252
	Y2	402264	0	402264
	Y3	270792	650240	921032
BARKA	Y1	53696	7314	61010
	Y2	3204	324058	327262
	Y3	271944	0	271944
BCFC	Y1	2716536	0	2716536
	Y2	258804	0	258804
	Y3	7423224	0	7423224
BMB	Y1	3872000	0	3872000
	Y2	3623724	0	3623724
	Y3	6232000	0	6232000
ESTERAD	Y1	72912	0	72912
	Y2	254502	0	254502
	Y3	435280	0	435280
GFH	Y1	6168	64901	71069
	Y2	20052	404405	424457

	Y3	257664	2778	26044
UGB	Y1	349048	0	349048
	Y2	221769	143636	365405
	Y3	1605520	0	1605520

V. CONCLUSIONS

This study investigated the performance efficiency of listed firms in BHB. A sample of 17 listed banks and investment firms was used in the current study. Both models of the DEA (CCR – BCC Models) were employed for measuring CRS and VRS of the sampled firms. DEA results were obtained through the use of a software that is DEAP 2.1 version. The first model (CCR Model) help in measuring the overall technical performance efficiency of the sampled firms; while the second model (BCC Model) help in measuring VRS (pure technical efficiency and scale efficiency as two components of the overall technical efficiency) of each sampled firm. The findings of the study revealed mixing results throughout the study period (2013-2017). For example, in 2017, the level of efficiency with CRS scores ranging from 0.275 to 1, whereas VRS efficiency scores range from 0.334 to 1.00. Also, with CRS scores, there are 7 efficient firms that got score 1 while, the other 10 firms are inefficient. in 2016, the level of efficiency with CRS scores ranging from 0.272 to 1, whereas VRS efficiency scores range from 0.28 to 1. One of our main finding indicates that among the five years included in the current study, the year 2013 has witnessed the highest level of performance efficiency especially when based on CRS. This study is not free from limitations. The sample size (17 firms) is relatively small. Although it can contribute to understanding the measurement of performance efficiency of listed firms in BHB, findings of such study could not be generalizable to other countries with dissimilar stages of development and business environment features. Consequently, it is highly recommended to replicate this study in other GCC countries which have many similarities to the Bahraini environment.

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Appendix (1)

Bank name	The code
Arab Banking Corporation BSC	ABC
Ahli United Bank BSC	AUB
BBK BSC	BBK
National Bank of Bahrain BSC	NBB
The Bahraini Saudi Bank	BSB
Al Baraka Banking Group BSC	BARKA
Khaleeji Commercial Bank BSC	KHCB
Bahrain Commercial Facilities Company	BCFC
Bahrain Middle East Bank	BMB
Esterad Investment Company B.S.C	ESTERAD
GFH Financial Group B.S.C	GFH
INOVEST B.S.C.	INOVEST
Investcorp Bank B.S.C.	INVCORP
Taib Bank B.S.C.	TAIB
United Gulf Investment Corporation B.S.C	UGIC
Gulf Monetary Group B.S.C	GMG
United Gulf Bank	UGB