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Applying DEA in Analysing the Efficiency of Top Manufacturing Companies in Pakistan

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Abstract

The efficiency of manufacturing companies is one of the critical elements for its competitiveness in the domestic as well as international markets. Previous research on efficiency measurement usually adopts Data Envelopment Analysis (DEA) approach. Therefore this paper is aimed to analyse the efficiency of 14 top manufacturing companies in Pakistan for a five year period from 2006 to 2010. Data of top 14 manufacturing companies are gathered from OSIRIS database. DEA method is applied using both the Constant Returns to Scale (CCR) and Variable Returns to Scale (BCC) models to find the overall efficiency, technical efficiency and scale efficiency. In this paper we use two input variables (total expenses and total assets) and two output variables (sales and profit before tax). The results under CCR method show that only one company is considered technically efficient while the average overall technical efficiency varies from 0.64 to 0.99. Company number 5 (NRL) demonstrates the best performance for all years under study.

Keywords: Efficiency, Data Envelopment Analysis, CCR model, BCC model, top manufacturing companies, Pakistan

1. Introduction

A business entity nowadays has to be efficient in order to perform and stay in business. Many experts define performance in different ways. Watkins (2007) defined performance as valuable results, accomplishments or contributions of an individual/team or an organization, regardless of preferred or mandated processes. Enos (2007) defined performance as achievement of tangible, specific, measurable, worthwhile and personally meaningful goals. Efficiency measurement is one aspect of a company's performance. Efficiency can be measured with respect to maximization of output, minimization of cost or maximization of profits. A company is regarded as technically efficient if it is able to obtain maximum outputs from given inputs or minimise inputs used in the production of given outputs. The objective of producers is to avoid waste. Various studies have been carried out to examine the performance of companies. Many studies have used financial ratios such as sales (Wang, 2003), return on assets (Lin et al., 2005; Naser and Mokhtar, 2004), return on equity (Ponnu and Ramthandin, 2008), and return on invested capital (Hsu and Liu, 2008).

Measuring the efficiency is essential for this purpose as efficiency is an important characteristic of organizational performance. In order to compete with other firms in international market, business organizations such as manufacturing companies, banks, private companies whether big or small organizations must reach to their optimal performance. Therefore, one of the major objectives in today's world of business is to improve the performance (Mohamad and Said, 2010). Every country needs to see their organizations performing well with maximum efficiency and productivity. Hence, it is focus of all organizations to achieve this target in order to meet their goals.

If we take an example of Pakistani manufacturing sector, as the study relates to this, it has significant contribution in economic growth of Pakistan (Shah, 2011). It is one of the major sectors of Pakistan with shares in gross domestic product (GDP) about 18.7% in 2010-2011 (Economic survey of Pakistan). Over 5 years period (2006-2011) it has reduced from 19.1% in 2006-07, stable for 2007-08 onwards, 18.9%, 18.2%, 18.6% and 18.7% respectively, as shown in **Table 1**.

Table 1: Manufacturing sector as a percentage of GDP

2006-07	**2007-08**	**2008-09**	**2009-10**	**2010-11**
19.1	18.9	18.2	18.6	18.7
Source**:** Hassan, (2011)**,** Economic survey of Pakistan , 2010-2011				

This sector is further divided into 2 groups namely; large scale manufacturing (LSM) and small and medium enterprises (SMEs). Public and private investments are the main sources to boost growth rate. If we see the present year investment in manufacturing, it has declined to

11% which was due to heavy decline in private investment. Furthermore, it was shown as in **Table 2**, there is a decline of 26.7% in investment of large scale manufacturing (LSM) during the fiscal year of 2010-2011.

Table 2: Distribution of Industrial investment

Description	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**% Change**
Manufacturing	364.1	375.5	355.1	316.0	-11.0
Public	1.3	4.3	3.8	3.7	-3.5
Private	362.8	371.2	351.2	312.3	-11.1
Large scale manufacturing	271.8	254.9	220.1	161.2	-26.7
Public	1.3	4.3	3.8	3.7	-3.5
Private	270.6	250.7	216.2	157.5	-27.2
Small Scale Manufacturing	92.2	120.5	135.0	154.7	14.6
Private	92.2	120.5	135.0	154.7	14.6
Source: Adapted from Shah (2011)					

Bouton and Sumlinski (2000) reported that higher income countries tend to have higher private investment ratios than lower income countries. A report from Trade Development Authority of Pakistan (TDAP) in 2011 shows the total exports from June 2010 to January 2011 is about USD13.23 billion which has improved than last year's corresponding period with USD10.78 billion. This year exports are; Textile sector with 25.9% growth (USD7.450 billion) as compared to only USD5.918 billion in 2010; Food group with 13%; Petroleum & Coal with 26.4%; and Other Manufacturing with 7%, respectively. Moreover, SMEs are often called as backbone of economic growth of developing countries (OECD, 2002). In Pakistan, its significance can be seen by GDP in the year of 2009-2010 in which real GDP grew by 3.8% (Shah, 2011).

With this background, it is interesting if we could examine the efficiency levels of manufacturing companies in Pakistan. In this study, we will employ Data Envelopment analysis to examine the efficiency of top manufacturing companies for the period 2006 to 2010.

The objectives of this paper are as follows:

- To analyse the efficiency of top manufacturing companies in Pakistan using both the CCR and BCC models, and
- To analyse returns to scale

2. Literature Review

Efficiency measurement is one aspect of a company's performance. Efficiency can be measured with respect to maximization of output, minimization of cost or maximization of profits. A company is regarded as technically efficient if it is able to obtain maximum outputs from given inputs or minimise inputs used in the production of given outputs. The objective of producers is to avoid waste. Various studies have been carried out to examine the performance of companies. Many studies have used financial ratios such as sales (Wang, 2003), return on assets (Lin et al. 2005; Naser and Mokhtar, 2004), return on equity (Ponnu and Ramthandin, 2008), and return on invested capital (Hsu and Liu, 2008).

Some studies have used more advance methods to measure the performance of companies. (Thore *et. al*. (1994) examined the productive efficiency of U. S. computer manufacturers using DEA. Their results show that few corporations were able to stay at the productivity efficiency throughout the time period under study. Batra and Tan (2003) examined technical efficiency of SME using data from six countries – Malaysia, Indonesia, Mexico, Colombia, Taiwan (China) and Guatemala. Their study shows that technical efficiency rises with company size and that there is a substantial overlap in the distribution of efficiency across company sizes, with some small companies operating at the same or higher levels of efficiency than some large companies. Education and training of workers, investments in new technology, automation, and quality control were factors that distinguish more efficient companies from less efficient companies in all 6 countries under investigation.

Wang (2003) examined the performance of Taiwan's Steel Industries for the period 1970-1996, and the results show that technical efficiency along with industrial evolution is generally influenced by policy measures engaging in market liberalization and adaptation to advanced technology. On the other hand, Wu *et. al*. (2006) examined the performance of the retailing industry in Taiwan using DEA and found that on average almost half of the retailing companies were inefficient.

Using DEA-Based approach, Hong and Park (2007) report that through the application of SVM model (Support Vector Machine), they were able to evaluate an individual company and provide the efficiency of an IT venture business without comparing it with other companies. Variables such as total capital turnover, sales/employees and the productivity of employees were important financial information in evaluating the efficiency of an IT business venture.

Fang et al. (2008) apply DEA approach to measure efficiency or performance of Taiwan Printed Circuit Board (PCB) industry for 2004 to 2007. They chose 14 companies and used return on investment capital (ROIC) as inputs and sales and return on equity (ROE) as outputs. Their study showed that the company with high DEA efficiency are also has good performance.

Eslami *et. al*., (2009) in a study on 18 Iranian companies producing automobiles and automobile parts, reported that, 8 companies were efficient in 2005, out of which only 4 companies remained efficient in 2006.

In this paper, we use the data obtained from OSIRIS database from 2006 to 2010 of 14 manufacturing companies in Pakistan and apply the DEA model to measure the efficiency of

these companies. An empirical efficiency frontier is estimated for each year and for each company. We also utilize the returns to scale analysis to illustrate the change of the company's production scale, and the use the results to improve the efficiency.

3. Research Methodology

3.1 Research Scope and Framework

Figure 1 presents the research framework of this study. We first choose the sample out of 349 companies listed in OSIRIS database. Finally we choose 14 manufacturing companies which satisfy the following conditions:

1. The company exists in 2006 to 2010.
2. The assets size are ≥ USD45 million to be eligible for inclusion in the top companies.

In addition, in this study we need a small data set to enable us to analyse in details each company for each year. The list of companies is presented in **Appendix A**.

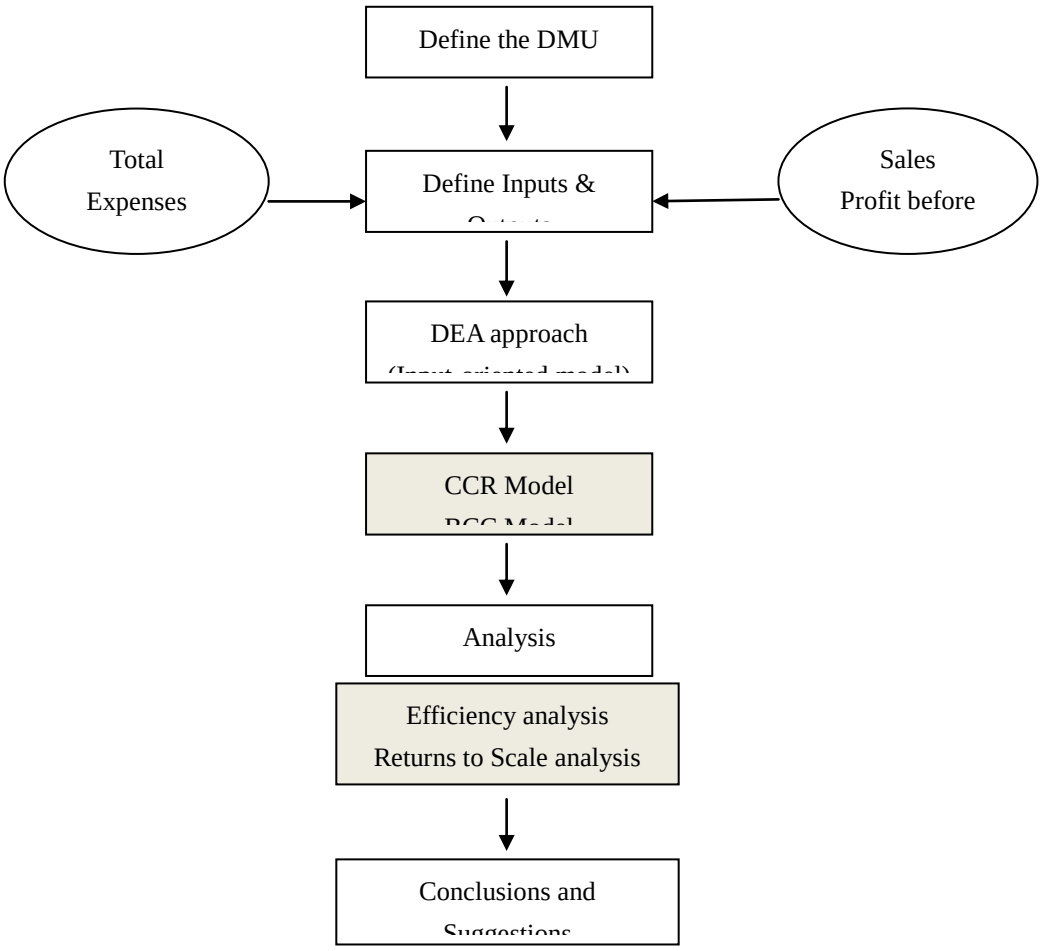

Figure 1: The Research Framework

3.2 Input and Output Variables

For inputs and outputs selection, we based on the previous works. **Table 3** summarizes the variables used by previous researchers.

Table 3: Variables references

No	Variables	References
1	Total Assets	(Yusof et al., 2010); (Wu and Ho, 2007); (Lin, et al., 2005); (Wang, 2008); (Mustafa, 2009);
2	Total Expenses	(Yusof et al., 2010)
3	Sales	(Yusof et al., 2010); (Lin, et al., 2005); (Wu et al., 2006); (Sharma, 2008); (Wang, 2008).
4	Profit before tax	(Wu and Ho, 2007)

Table 4 presents the descriptive statistics for the variables employed in this study**.** In terms of assets, total assets has increased for all the companies from 2006 to 2010 indicating that companies had expanded their size during the period. For expenses, the cost has increased from 2006 to 2009 but slightly decreased in 2010. Sales has increased from 2006 to 2008, decreased in 2009 but increased again in 2010 indicating that sales fluctuated over the five year period. On average, the fourteen companies' profit before tax has increased from 2006 to 2008, slightly decreased in 2009 but climbing up again in 2010. As a conclusion, the financial position of the top fourteen manufacturing companies in Pakistan had shown a slight fluctuation in terms of size, expenses, sales, and profit before tax.

Table 4: Descriptive Statistics of the input and outputs used (In TH USD)

	Mean	Std. Dev.	Minimum	Maximum
2006				
X_1	335,618	201,508	45,036	820,517
X_2	354,022	327,465	58,586	1,311,953
Y_1	371,946	336,105	62,786	1,342,328
Y_2	47,061	40,211	4,034	162,711
2007				
X_1	394,719	247,870	49,212	868,258
X_2	402,803	359,344	47,764	1,460,441
Y_1	413,685	371,563	57,223	1,508,971
Y_2	50,674	43,617	1,837	170,008

2008				
X_1	437,104	301,956	48,654	1,021,543
X_2	438,974	442,463	48,516	1,840,702
Y_1	450,869	457,276	51,931	1,894,908
Y_2	53,221	49,363	1,105	174,494
2009				
X_1	456,661	371,438	105,522	1,567,767
X_2	436,256	343,355	59,207	1,358,155
Y_1	443,077	342,439	64,240	1,346,344
Y_2	45,670	48,877	2,049	200,099
2010				
X_1	536,034	447,959	251,744	1,922,493
X_2	433,464	354,896	46,024	1,284,487
Y_1	501,780	371,588	44,562	1,289,281
Y_2	67,291	69,037	3,802	274,240
Note: X_1 = Total assets X_2 = Total expenses, Y_1 = Sales, Y_2 = Profit before Tax				

3.3 The DEA Model

In this study we employed the non-parametric measure, the DEA. It is non-parametric because it requires no assumption on the shape or parameters of the underlying production function. DEA is a linear programming technique based on the pioneering work of Farrell's efficiency measure (1957), to measure the different efficiency of decision-making units (DMUs). Assuming the number of DMUs is *s* and each DMU uses *m* inputs and produces *n* outputs. Let DMU_k be one of *s* decision units, $1 \leq k \leq s$. There are *m* inputs which are marked with X_i^k ($i = 1, ..., m$), and n outputs marked with Y_j^k ($j = 1,...., n$). The efficiency equals the total outputs divide by total inputs. The efficiency of DMU_k can be defined as follows:

$$\text{The efficiency of } DMU_k = \frac{\sum_{j=1}^{n} u_j Y_j^k}{\sum_{i=1}^{m} v_i X_i^k} \quad (1)$$

$X_i^k, Y_j^k \geq 0$, $i = 1,....,m$, $j = 1,...,n$, $k = 1,...,s$

$u_j\ v_i \geq 0$, $i = 1,...,m$, $j = 1,...,n$

The DEA program enables one to find the proper weights which maximise the efficiency of DMU and calculates the efficiency score and frontier. The CCR model originated by Charnes *et. al*. (1978), has led to several extensions, most notably the BCC model by Banker *et. al*. (1984). The CCR and BCC models can be divided into two terms; one is the input oriented model; the other is the output oriented model. The input orientation seeks to minimize the usage of inputs given a fixed level of output while the output orientation maximizes the level of output for a given level of inputs. The CCR model assumes constant returns to scale (CRS) which means one unit input can get fixed value of output. The BCC model assumes variables returns to scale (VRS).

In this study we chose the input oriented model and used a dual problem model to solve the problems. The CCR dual model is as follows:

$$Min\theta - \varepsilon \qquad [\ \sum_{i=1}^{m} S_i^- + \sum_{k=1}^{n} S_j^+\ ] \qquad (2)$$

$$s.t. \sum_{i=1}^{s} \lambda_r X_i^r - \theta X_i^k + S_i^- = 0 \qquad i = 1, ..., m$$

$$\sum_{i=1}^{s} \lambda_r Y_j^r - S_i^+ = Y_j^r \qquad j = 1, ..., n$$

$$\lambda_r \geq 0 \qquad r = 1,..., s$$

$$S_i^- \geq 0 \qquad i = 1,..., m$$

$$S_j^+ \geq 0 \qquad j = 1,..., n$$

Where

θ is the efficiency of DMU

S_i^- is the slack variable which represents the input excess value,

S_j^+ is the surplus variable represents the output shortfall value,

ε is a non-Archimedean number which represents a very small constant,

λ_r means the proportion of referencing DMU_r when measure the efficiency of DMU_k.

If the constraint below is adjoined, the CCR dual model is known as the BCC model.

$$\sum_{i=1}^{s} \lambda_r = 1 \quad (3)$$

Equation (3) frees CRS and makes the BCC model to be VRS. For the measurement of efficiency, the CCR model measures overall efficiency (OE) of a DMU, and the BCC model can measure both the pure technical efficiency (PTE) and scale efficiency (SE) of the DMU. The relationship of OE, PTE and SE is as the equation (4) below.

OE = PTE X SE (4)

DEA technique has been applied successfully as a performance measurement tool in many fields including the manufacturing sector, hospitals, pharmaceutical firms, banks, education and transportation. In this study, an input orientation as opposed to output orientation has been adopted.

4. Empirical Results

4.1 Efficiency of the Top Manufacturing Companies in Pakistan

To take account of the year effects, we chose to calculate different technology per year which implicitly incorporates time effects of our analysis instead of computing a common benchmark for the whole sample (74 over the five year period). **Table 5** presents the descriptive statistics of the various efficiency score for top manufacturing companies in Pakistan for the year 2006 to 2010, using both the CCR and BCC models. The CCR model assumes constant returns to scale while the BCC model allows for variables returns to scale. The results suggest the mean technical efficiency of top manufacturing companies in Pakistan has been on an increasing trend from 2006 to 2008 before declining in 2009 and 2010. From the table, top companies in Pakistan have exhibited mean technical efficiency of 0.94 in 2006 and 2007, increased to 0.96 in 2008, decreased to 0.90 in 2009 and to 0.64 in 2010.

Table 5: Descriptive Statistics of Efficiency Measures, 2006-2010

		Mean	Median	Maximum	Minimum	S.D
2006	Technical Efficiency	0.94	0.96	1.00	0.83	0.06
	Pure Technical Efficiency	0.97	0.99	1.00	0.89	0.04
	Scale Efficiency	0.97	0.98	1.00	0.91	0.03
2007	Technical Efficiency	0.94	0.94	1.00	0.82	0.07
	Pure Technical Efficiency	0.96	1.00	1.00	0.83	0.06
	Scale Efficiency	0.98	0.99	1.00	0.92	0.03
2008	Technical Efficiency	0.96	0.95	1.00	0.86	0.05
	Pure Technical Efficiency	0.96	0.98	1.00	0.86	0.05
	Scale Efficiency	0.99	1.00	1.00	0.95	0.01
2009	Technical Efficiency	0.90	0.87	1.00	0.79	0.08
	Pure Technical Efficiency	0.92	0.91	1.00	0.82	0.08
	Scale Efficiency	0.98	1.00	1.00	0.88	0.04
2010	Technical Efficiency	0.64	0.68	1.00	0.18	0.33
	Pure Technical Efficiency	0.89	1.00	1.00	0.28	0.21
	Scale Efficiency	0.73	0.84	1.00	0.18	0.31
	Note: SD = Standard Deviations, Overall efficiency under Constant Returns to Scale, Pure Technical Efficiency under Variable Returns to Scale.					

Table 6 summarizes the efficiency scores evaluated for each company in year 2006 to 2010. From the CCR model analysis, company number 5 i.e. NRL was efficient in all five years. FFC was inefficient in 2006 but efficient in 2007 to 2010. All companies were technically efficient in 2006 to 2009 but LUCK, ENGRO, ICI, SIEM, NCL, FCCL and LIBM were technically inefficient for 2010.

4.2 Analysis of Returns to Scale

As mentioned earlier, we utilize the returns to scale analysis to illustrate the change of company's production scale. The returns to scale analysis are shown in **Table 6**. The constant returns to scale indicate that the company has reached the best scale. The increasing returns to scale indicates that an increase in inputs leads to a more than proportionate increase in output while decreasing returns to scale indicates that an increase in inputs leads to a less

proportionate increase in outputs.

Table 7 shows the companies that lie on the efficiency frontier. The composition of the companies that lie in the efficiency frontier suggests that the 100 percent efficient companies vary between three to six companies. During the period under investigation, five companies have failed to appear at least once on the frontier while FFC and NRL were the leaders by appearing most on the efficiency frontier. Companies that have exhibited IRS in their operations indicated that a proportionate increase in inputs would result in more than a proportional increase in outputs. Hence these companies which have been operating at IRS could save costs and gain efficiency by increasing its scale of operations. This could be done through internal growth or perhaps consolidation in the manufacturing sector.

Table 6: Efficiency Scores for Each Company, 2006-2010

No	DMU	Efficiency	2006	2007	2008	2009	2010	AVG
1	FFC	TE	0.95	1	1	1	1	0.99
		PTE	1	1	1	1	1	1
		SE	0.95	1	1	1	1	0.99
2	NML	TE	0.83	0.82	1	0.83	0.87	0.87
		PTE	0.89	0.90	1	0.84	0.92	0.91
		SE	0.93	0.92	1	1	0.94	0.96
3	IBFL	TE	0.89	0.89	0.96	0.82	0.60	0.82
		PTE	0.92	0.92	0.96	0.82	0.92	0.91
		SE	0.97	0.97	0.99	0.99	0.66	0.91
4	FFBL	TE	0.89	1	0.92	0.9	0.92	0.93
		PTE	0.95	1	0.92	0.9	1	0.95
		SE	0.94	1	1	1	0.92	0.97
5	NRL	TE	1	1	1	1	1	1
		PTE	1	1	1	1	1	1
		SE	1	1	1	1	1	1
6	LUCK	TE	1	0.93	1	1	0.47	0.85
		PTE	1	1	1	1	0.72	0.94
		SE	1	0.93	1	1	0.66	0.91
7	ENGRO	TE	0.95	0.94	0.91	0.85	0.27	0.71
		PTE	0.98	1	0.92	0.92	0.28	0.75
		SE	0.97	0.94	0.98	0.92	0.98	0.96
8	ICI	TE	0.96	0.98	0.95	0.84	0.76	0.9
		PTE	0.98	1	0.95	0.84	1	0.95
		SE	0.98	0.98	1	0.99	0.76	0.94
9	INDU	TE	1	1	1	0.86	0.99	0.97
		PTE	1	1	1	0.86	1	0.97
		SE	1	1	1	1	0.99	1
10	SIEM	TE	0.96	0.85	0.91	0.83	0.49	0.79
		PTE	0.97	0.86	0.92	0.83	0.91	0.90
		SE	1	0.99	0.99	1	0.54	0.88

11	NESTLE	TE	0.99	0.93	0.94	1	1	0.97
		PTE	1	0.94	0.94	1	1	0.97
		SE	1	1	1	1	1	1
12	NCL	TE	0.88	0.83	0.86	0.79	0.22	0.64
		PTE	0.89	0.83	0.86	0.82	0.67	0.81
		SE	0.98	1	1	0.96	0.32	0.79
13	FCCL	TE	1	1	0.95	1	0.18	0.70
		PTE	1	1	1	1	1	1
		SE	1	1	0.95	1	0.18	0.70
14	LIBM	TE	0.91	0.94	1	0.88	0.21	0.69
		PTE	1	1	1	1	1	1
		SE	0.91	0.94	1	0.88	0.21	0.69
Note: OE = Overall efficiency, PTE = Pure technical efficiency, SE = Scale Efficiency								

Table 7: Return to Scale (RTS) of Each Company, 2006-2010

No	**Company**	**2006**	**2007**	**2008**	**2009**	**2010**	**Count Co.**
1	FFC	DRS	CRS	CRS	CRS	CRS	4
2	NML	DRS	DRS	CRS	IRS	DRS	1
3	IBFL	DRS	DRS	DRS	IRS	IRS	0
4	FFBL	DRS	CRS	DRS	IRS	IRS	1
5	NRL	CRS	CRS	CRS	CRS	CRS	5
6	LUCK	CRS	DRS	CRS	CRS	IRS	3
7	ENGRO	DRS	DRS	DRS	DRS	IRS	0
8	ICI	DRS	DRS	DRS	IRS	IRS	0
9	INDU	CRS	CRS	CRS	IRS	DRS	3
10	SIEM	DRS	DRS	DRS	IRS	IRS	0
11	NESTLE	DRS	DRS	DRS	CRS	CRS	2
12	NCL	DRS	DRS	DRS	IRS	IRS	0
13	FCCL	CRS	CRS	IRS	CRS	IRS	3
14	LIBM	IRS	IRS	CRS	IRS	IRS	1
Count Year		4	5	6	5	3	

Note: CRS = Constant returns to scale, DRS = Decreasing returns to scale, IRS = Increasing returns to scale.

Shaded areas show that companies have not been efficient in any year in the sample period.

Count Co. denotes the number of companies appearing on the efficiency frontier during the year and Count Year refers to number of times a company has appeared on the efficiency frontier during the period under study

5 Conclusions and Directions for Future Research

This paper examines the relative efficiency of top manufacturing companies in Pakistan using the non-parametric approach of data envelopment analysis (DEA) from 2006 to 2010. The DEA methodology is employed using both the constant returns to scale (CRS) and variable returns to scale (VRS) assumptions to provide measures of technical and scale efficiency.

The results reveal a substantial level of dispersion of technical efficiency between companies within the sample for the year to year basis. The estimated results show that only 1 company is relatively efficient throughout the period under investigation while the average overall technical efficiency varies from 0.64 to 0.96. We found that the source of inefficiency is majority due to its scale rather than pure technical inefficiency. This is consistent to the study by Lu and Hung (2010). The inefficient companies can effectively promote resource utilization efficiency by better handling their inputs.

This study is not without its limitations. More companies should be included in the study and other input and output variables could be used. Further, slack analysis could also be included to make decision on what and how much to reduce unnecessary expenses. However, the findings could help the management of the company to review its resources to increase performance and efficiency.

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Appendix A

List of Companies and Abbreviations

Company	**Ticker no.**	**Company**	**Ticker no.**
Fauji Fertilizer Company	FFC	ICI Pakistan Limited	ICI
Nishat Mills Limited	NML	Indus Motors Corporation Limited	INDU
Ibrahim Fibre Limited	IBFL	Seimens (Pakistan) Engineering Company Limited	SIEM
Fauji Fertilizer Bin Qasim Limited	FFBL	Nestle Pakistan Limited	NESTLE
National Refinery Limited	NRL	Nishat (Chunian) Limited	NCL
Lucky Cement Limited	LUCK	Fauji Cement Company Limited	FCCL
Engro Corporation Limited	ENGRO	Liberty Mills Limited	LIBM
Source: OSIRIS database			