Relative Efficiency of Manufacturing Companies in Pakistan Using Data Envelopment Analysis

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Abstract

The performance of companies is vital as it provides financial view to the stake holders. One of the approaches to examine the performance is to look at the efficiency levels of the companies in utilizing their inputs to produce outputs. In this paper efficiency evaluation is done on 49 manufacturing companies in Pakistan for the period 2008-2010. Input-oriented DEA model under constant return to scale (CRS) and variable return to scale (VRS) is employed. Four inputs (raw material, staff expenses, plant & machinery and cost of goods sold) and two outputs (net sales and earnings after tax) are employed to analyze technical, pure technical and scale efficiency scores. The results on individual company indicate that 16 percent of the companies are consistently operating at the most productive scale size (MPSS) throughout the study period on both efficiency parameters (CRS and VRS). 20 percent of the companies have operated at the MPSS, at least one out of three years. The results also indicate that on average, inefficient companies in Pakistan could reduce their inputs relative to the best practise companies during 2008 to 2010.
Keywords: Efficiency, Data Envelopment Analysis, Companies, Pakistan

1. Introduction

Pakistani manufacturing sector has made a significant contribution in the economic growth of Pakistan (Shah, 2011**)**. It is one of the major sectors of Pakistan with shares in gross domestic product (GDP) of about 18.7 percent in 2010-2011 (Shah, 2011). Manufacturing sector is one of the dominating sectors in Pakistan. Being an influential sector, it has great importance in the economy of the country. **Table 1** presents the shares of industrial and manufacturing sector in terms of GDP. From the table, it can be seen that, the manufacturing sector which is made of large and small scale, has contributed 16 percent to GDP in 1969-1970, decreased to 14.7 percent in 1999-2000, increased to 18.3 percent in 2004-2005 and to 19.2 percent in 2007-2008. Its share fell slightly to 18.2 percent in 2008-2009 and increased again to 18.6 percent in 2009-2010 and to 18.7 percent in 2010-2011.

The global financial crisis of 2008 has influenced on the growth of large-scale manufacturing sector as well. The growth in large scale manufacturing sector in 2008 was minus 8.2 (Shah, 2011). Habib-ur-Rehman. (2009**)** reported that the reasons of slower growth in large scale manufacturing sector include high inflation, weak in the domestic and external demand. The international experience suggests that lack of growth momentum in this sector can be the result of low quality products, lack of research and development, inadequate investment, minimal exposure to the international market, inadequate infra structure and unskilled labour **(**Shah, 2011).

Public and private investments are the main sources to boost growth rate. **Table 2** demonstrates that there is a decline of investment in the public and the private manufacturing sector. Large scale manufacturing also records a decline of 26.7 percent during the fiscal year of 2010-2011, whereas the small scale manufacturing records an increase.

Therefore, every country needs to emphasize on the efficiency and productivity of their industrial as well manufacturing sector so as to achieve optimal growth. A business entity nowadays has to be efficient in order to be competent, perform well and stay in business.

The objectives of this paper are: (i) o estimate the overall technical (OTE), pure technical (PTE) and scale efficiencies (SE) of companies in the manufacturing sector in Pakistan by using Data Envelopment Analysis; (ii) to identify the individual companies operating at most productive sale size (MPSS); (iii) to examine return to scale; and (iv) to set input-output targets for inefficient companies to improve their efficiencies. The paper is organized as follows. The next section provides an overview of previous research; methodology is discussed in Section 3; Section 4 presents the results followed by conclusions in Section 5.

2. Literature Review

Efficiency is very important for this purpose, as it is an important characteristic of an organizational performance. In order to compete with other firms in market, business organizations such as manufacturing companies, banks, private companies whether big or small must reach to their optimal performance. Mohamad and Said, (2010) suggest that one of the major objectives in today's world of business is to improve the performance. What is performance? Many experts define performance in different ways. Efficiency measurement is one aspect of a company's performance. It 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 produce maximum outputs from given inputs or minimise inputs used in the production of given outputs. So, the objective of the producers is to avoid waste.

Various studies have been carried out to examine the efficiency of companies. Farell, (1957) empirically measured the efficiency for first time and Charnes et al., (1978) developed a new tool called Data Envelopment Analysis (DEA) by generalizing the concept of single input, single output technical efficiency measure of Farrell's to the multiple inputs and multiple output case. The model is known as CCR model. It was further extended by Banker, Charnes and Cooper in 1984 (BCC model) This method uses a set of decision making units (DMUs) which combines the multiple inputs and outputs to measure the relative efficiency. Thore *et al*., (1994) examine the productive efficiency of U. S. computer manufacturers using DEA. Their results showed that few corporations were able to stay at the productivity efficiency throughout the time period under study.

Batra and Tan (2003) on the other hand, examined technical efficiency of SME using data from six countries –Malaysia, Indonesia, Mexico, Colombia, Taiwan (China) and Guatemala. Their study showed that technical efficiency rise with company size and that there was 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.

Wu (2005) examined the performance of Taiwan's Steel Industries for the period 1970-1996, and the results showed 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) reported 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. Din et al., (2007) investigated the technical efficiency of the large scale manufacturing sector in Pakistan using DEA approach by output oriented model under CRS and VRS assumption. Data were collected from 101 industries for 2 periods as 1995 to 96 and 2000 to 2001. Inputs employed include capital, labour, industrial cost and non-industrial cost and output was contribution of GDP. Under constant return to scale (CRS), the results indicated that mean efficiency has improved from 0.23 in 1995-96 to 0.42 in 2000-01 and only 2 industries could maintain their ranking in both periods. Whereas, under variable return to scale, average efficiency score has increased from 0.31 in first period to 0.49 in second period. A study was done by Singh, (2006-2007) to assess the performance of sugar mills in Uttar Pradesh using DEA. The study found that the overall technical efficiency of sugar mills for the period 1996-97 to 2002-2003 was 93 percent and the mills could make 7 percent reduction in all inputs to become as efficient as the mills in their reference set. Private sectors had higher level of performance due to large plant size as compared to cooperative and government sectors. Man power and energy inputs were the factors that were found to be highly underutilized, in the inefficient mills.

Meenakumari and Kumaraj, (2008) employed DEA model under CRS and VRS assumption to evaluate relative efficiency of 29 State owned Electric utilities (SOEU's) in India. Data was collected from TERI Energy Data Directory and Yearbook 2004/05. Primarily, correlation between inputs and outputs were examined through regression analysis and found that inputs and outputs were positively correlated to each other. The results from their study showed that over 24 percent SOEU's were efficient under CRS and VRS. Joshi and Singh, (2009) measured production efficiency of readymade garment firms in India by DEA approach using CCR and BCC models. Research was based on eight garment firms and primary data was used. Number of stitching machines and the number of operators were selected as input factors; and total pieces of garment produced, selected as an output factor. Firstly, a correlation analysis was done, which indicated that output is significantly related to inputs. Their results showed that firms had average efficiency of 0.75 and could increase output by 25 percent with existing inputs under CRS technology. Under VRS technology, it was found that firms were 17 percent inefficient in pure production efficiency and 9 percent inefficient in scale efficiency. Moreover, under return to scale analysis, most of the firms were operating under decreasing return to scale and production efficiency could be improved by target inputs and outputs to reach the DMU's in reference set.

Mohamad and Said, (2010) attempted an interesting work and assessed the performance of MB100 companies in Malaysia. Input variable was, total operating expenditure (cost); and output variables were rate of change of revenue, rate of change of net profit, rate of change of assets, the return on revenue, return on equity and return on assets. DEA technique was employed to evaluate efficiency under CRS and VRS assumptions. 6 percent companies were efficient under CRS and 19 percent were efficient under VRS assumption; and only 6 percent could achieve scale efficiency. However, these top performers were revenue-bottom-ranked companies and no companies exhibited increasing return to scale. Revenue of top ranked companies showed decreasing return to scale and serious scale inefficiency. Hence, this study illustrated peer units for inefficient companies as a reference set.

Beriha et al., (2011) applied DEA constant return to scale (CRS) model to calculate technical efficiency and to identify the benchmarking units for safety performance in Indian industries. Numbers of accidents in units were taken as outputs; and percentage of annual budget for various safety activities, taken as inputs. Seven units out of thirty were found to be efficient under CRS model. Benchmarking was done for inefficient units to become efficient one.

3. Methodology

3.1 Data

This study is based a secondary data obtained from OSIRIS database. 49 sample companies are selected based on the availability of the variables that we employed in the study and the companies are in existence for the three periods – 2008 to 2010. A list of the companies along with their ticker code is presented in Appendix 2.

3.2 Inputs and Outputs

To select the input and output variables for the DEA model used in this study, we take into account factors that affect the overall production processes which include costs, materials, plant and machinery and profits were under our considerations. Based on the review of past studies, four input variables and two output variables were chosen. **Table 3** presents the input-output variables used and authors that have used them in their studies.

The descriptive statistics of these input-output variables are given in Appendix 1. The descriptive statistics show that mean values of all input variables have decreased during the period under study. The mean values of output variables also show similar pattern.

3.3 Research 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:

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

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

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:

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

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

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

$\lambda_r \geq 0 \quad r = 1,..., s$
$S_i^- \geq 0 \quad i = 1,..., m$
$S_j^+ \geq 0 \quad j = 1,..., n$

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.

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

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.

SE = OTE/PTE (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. Results

4.1 Efficiency Analysis

Input-oriented CCR and BCC DEA models are applied in this study to calculate the overall technical efficiency (OTE), pure technical efficiency (PTE) and scale efficiency (SE) of manufacturing companies in Pakistan. To take account of the year effects, we chose to calculate a different technology per year which implicitly incorporates the time effects of our analysis instead of computing a common benchmark for the whole of accumulated sample (147 companies over 3 years). **Table 4** presents the descriptive statistics for the period 2008 to 2010. The descriptive statistics comprises the mean, standard deviation, minimum and maximum values of the efficiency scores.

The OTE scores indicate that companies having value of 1 are on the efficient frontier under constant returns to scale (CRS) technology assumption and those having values less than 1 are below the frontier. The lower the efficiency score, the higher will be the scope for reduction in their inputs (while maintaining the levels of outputs) relative to the best practice companies. From the table, the mean OTE has decreased from 0.864 in 2008 to 0.854 in 2009 and to 0.828 in 2010. The results also indicate that the OTE scores are not only decreasing during the three-year period, but also have relatively higher variations across companies as indicated by standard deviation, minimum and maximum values. In terms of OTE, we can see that 26 percent of the sampled companies were on the efficient frontier in 2008 and 2010 while in 2009 only 24 percent of the sampled companies were on the efficient frontier.

The values for pure technical efficiency (PTE) are estimated by the BCC model which is based on VRS technology assumption. The results from **Table 4** show that on average PTE scores are higher than OTE scores, implying that most of the companies were able to convert their inputs efficiently into output but some may be due to disadvantageous in plant sizes. We observe that the average PTE scores have decreased slightly over the three-year period. There are considerable variations in terms of the scores as evidenced by the minimum and maximum values. The values for the standard deviation are relatively lower than that of the standard deviation for OTE implying that the variation in the performance is largely due to variation in plant sizes.

The scale efficiency measures the divergence between the efficiency rating under CRS and VRS technology assumptions. SE is ratio OTE to PTE scores. The SE analysis show how optimal individual companies use their scales As OTE of the DMU can never exceed its PTE, the value of SE≤1. If the value is one, then the company is operating at the optimal scale. If the value is less than one, the company appears either too small or too big relative to its optimum size. According to **Table 4**, the average SE shows a similar pattern for the three periods.18 companies in 2008, 19 companies in 2009 and 21 companies in 2010 are fully efficient according to scale analysis.

The DEA also evaluates each individual company under CRS and VRS technology assumptions. **Table 5** provides information on each individual company. If a company scores efficiency value of both CCR and BCC models of one, it operates at the most productive scale size (MPSS). Out of 49 companies, 8 companies (3, 4, 12, 16, 28, 31, 33, and 40) have been consistently operating at the MPSS throughout the study period. 10 companies (5, 9, 18, 19, 22, 23, 26, 39, 46, and 49) have operated at the MPSS, at least one out of three years. Thus, we can conclude here that except for few companies which are able to maintain their performance throughout the period under observation, most of the companies do not have consistency in their performance across the years.

4.2 Returns to Scale Analysis

We further investigate the situation and utilize the returns to scale analysis to illustrate the change of the company's production scale. The returns to scale analysis are shown in **Table 6**. The constant return to scale (CRS) indicates that the company has reached the best scale. The increasing return to scale indicates that an increase in inputs leads to a more than proportionate increase in output while decreasing return to scale indicates that an increase in inputs leads to a less proportionate increase in outputs.

In 2008, 7 companies (14.3 percent) are operating at decreasing return to scale, 29 companies (59.2 percent) are operating at increasing returns to scale while in 2010, 13 companies (26.5 percent) are operating at constant return to scale. In 2009, the results indicate that 14 companies (28.6 percent) are operating at DRS, 23 companies (46.9 percent) are operating at IRS while 12 companies (24.5 percent) are operating at CRS. In 2010 more companies are operating at DRS (22 or 44.9 percent), 14 companies or 28.6 percent are operating at IRS and 13 companies or 26.5 percent are operating at CRS. Overall, only 8 companies or 16.3 percent are consistently operating at CRS.

4.3 Analysis of Input-Output Targets for the Inefficient Companies

We further perform the analysis of slack variables to understand the improvements that the inefficient companies have to make on inputs. In DEA, it enables the programme to identify inputs and outputs levels that would make a company relatively efficient. These levels can be used as a basis for setting performance targets. So, each of the inefficient companies can become efficient by adjusting its operation to the associated target point determined by the efficient companies that define its reference set.

Table 7 presents the percentage reduction in the observed values of inputs required to make it efficient. It can be seen from the table that on average, inefficient companies in Pakistan could reduce their inputs relative to the best practise companies during 2008 to 2010. If we look at the year-wise figures of targeted inputs and percentages of reduction required in the different inputs, there appears to be a small variation in these figures across the years For example, in 2008, on average, approximately 34 percent of raw material, 22 percent of staff expenses, 29 percent of plant and machinery and 19 percent of cost of goods sold could be reduced to produce the given level output if an average inefficient companies is to operate at the level of efficient companies. In 2010, on average, approximately 32 percent of raw material, 27 percent of staff expenses, 30 percent of plant and machinery and 24 percent of cost of goods sold should be reduced. Looking at the individual company for example, we observe that staff expenses and plant and machinery are under-utilized in DMU1. Plant and machinery are found to be under-utilized in DMU2, DMU6 and DMU13. These inefficient companies are required to reduce their inputs to the targeted levels to produce the existing level of output. Alternatively, they can expand their outputs so as to utilize the excess quantity of inputs in an efficient manner.

5. Conclusions

This paper examined the relative efficiency of 49 manufacturing companies in Pakistan using the non-parametric approach of Data Envelopment Analysis (DEA) from 2008 to 2010. The DEA methodology is employed using both the constant return to scale (CRS) and variable return to scale (VRS) technology assumptions to provide measures of technical and scale efficiency.

In terms of OTE, the results indicate that 26 percent of the sampled companies were on the efficient frontier in 2008 and 2010 while in 2009 only 24 percent of the sampled companies were on the efficient frontier. The results for pure technical efficiency (PTE) show that on average PTE scores are higher than OTE scores, implying that most of the companies were able to convert their inputs efficiently into output but some may be due to disadvantageous in plant sizes. We observe that the average PTE scores have decreased slightly over the three-year period. There are considerable variations in terms of the scores as evidenced by the minimum and maximum values. The values for the standard deviation are relatively lower than that of the standard deviation for OTE implying that the variation in the performance is largely due to variation in plant sizes. Our results also show that the average SE shows a similar pattern for the three periods.18 companies in 2008, 19 companies in 2009 and 21 companies in 2010 are fully efficient according to scale analysis.

The results on individual company show that of 49 companies, 16 percent of the sampled companies have been consistently operating at the most productive scale size (MPSS) throughout the study period. 20 percent of the companies have operated at the MPSS, at least one out of three years. Thus, we can conclude here that except for few companies which are able to maintain their performance throughout the period under observation, most of the companies do not have consistency in their performance across the years.

The results of the input-output targets analysis indicate that there is a small variation in the percentages of reduction required in the different inputs across the years. Many of inefficient companies are under-utilizing their staff expenses and plant and machinery. These inefficient companies are required to reduce their inputs to the targeted levels to produce the existing level of output. Alternatively, they can expand their outputs so as to utilize the excess quantity of inputs in an efficient manner.

In this study, there are limitations that should be considered. The companies that we use in this study are of different categories but majority of the companies are textile companies since textile formed the largest companies in the manufacturing sector in Pakistan. Since this is the first study, the use of DEA is appropriate and as far as we are aware, this is the first study of its kind using manufacturing companies in Pakistan as a setting.

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Table 1: Manufacturing Sector as a percentage of GDP

	1969-70	1999-00	2004-05	2007-08	2008-09	2009-10	2010-11
INDUSTRIAL SECTOR	22.7	23.3	26.3	25.8	25.3	26.4	25.8
Mining & Quarrying	0.5	2.3	2.7	2.6	2.5	2.5	2.4
Manufacturing	**16**	**14.7**	**18.3**	**19.2**	**18.2**	**18.6**	**18.7**
I. Large Scale	12.5	9.5	12.9	13.4	12.1	12.3	12.1
II. Small Scale	3.5	5.2	4.1	4.4	4.7	4.9	5.1
Construction	4.2	2.5	2.1	2.4	2.1	2.6	2.5
Electricity & Gas Distribution	2	3.9	3.2	1.6	2.5	2.8	2.2
Source: (Zafar-ul-Hassan, 2009 and 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: Shah (2011)					

Table 3: Input, Output and References

Variables	**References**
Input	
Raw Material	Mazumdar and Rajeev, 2009; Sharma, 2008; Ar and Baki, 2007; Singh, 2007; Wu, 2005.
Staff Expenses	Mazumdar and Rajeev, 2009; Sharma, 2008.
Plant & Machinery	Mazumdar and Rajeev, 2009; Singh, 2007; Ar and Baki, 2007.
Cost of Goods sold	Ali Mohammadi and Habibollah Ranaei, 2011; Fang et al., 2008; Lin et al., 2005.
Output	
Net Sales	Yusof et al., 2010; Sharma, S. 2008; Wang. 2008; Lin, et al., 2005; Wu et al., 2006.
Earnings after tax	Ling and Kamil, 2010; Qian and Dawai, 2009.

Table 4: Descriptive Statistics of OTE, PTE and SE, 2008-2010

Types of Efficiency	Descriptive Statistics	2008	2009	2010
OTE	Mean	0.864	0.854	0.828
	Minimum	0.670	0.661	0.579
	Maximum	1.00	1.00	1.00
	Standard Deviation	0.108	0.116	0.147
	No. of Efficient Companies	13	12	13
		(26.5)	(24.5)	(26.5)
	Total no. of Companies	49	49	49
PTE	Mean	0.899	0.887	0.866
	Minimum	0.695	0.680	0.612
	Maximum	1.00	1.00	1.00
	Standard Deviation	0.101	0.114	0.145
	No. of Efficient Companies	20	20	22
		(40.8)	(40.8)	(44.9)
	Total no. of Companies	49	49	49
SE	Mean	0.962	0.964	0.957
	Minimum	0.716	0.726	0.721
	Maximum	1.00	1.00	1.00
	Standard Deviations	0.065	0.063	0.068
	No. of Efficient Companies	18	19	21
		(36.7)	(38.8)	(42.9)
	Total no. of Companies	49	49	49

Note: Figures in parentheses are percentages of efficient companies to total companies under survey.

Table 5: Overall Technical Efficiency, Pure Technical Efficiency and Scale Efficiency

	2008				2009				2010			
DMU	**OTE**	**PTE**	**SE**	**EFF/ INEFF**	**OTE**	**PTE**	**SE**	**EFF/ INEFF**	**OTE**	**PTE**	**SE**	**EFF/ INEFF**
1	0.72	1.00	0.72	INEFF	0.92	1.00	0.92	INEFF	1.00	1.00	1.00	EFF
2	0.80	0.80	1.00	INEFF	0.94	0.97	0.97	INEFF	0.70	0.76	0.92	INEFF
3	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
4	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
5	0.93	0.93	1.00	INEFF	1.00	1.00	1.00	EFF	0.76	0.85	0.89	INEFF
6	0.85	1.00	0.85	INEFF	0.85	0.86	0.98	INEFF	0.89	1.00	0.89	INEFF
7	0.79	0.80	0.99	INEFF	0.74	0.75	0.99	EFF	0.67	0.69	0.97	INEFF
8	0.69	0.70	0.99	INEFF	0.90	0.92	0.98	INEFF	0.96	1.00	0.96	INEFF
9	1.00	1.00	1.00	EFF	0.77	0.82	0.93	EFF	0.68	0.75	0.91	INEFF
10	0.78	0.78	1.00	INEFF	0.73	0.75	0.97	INEFF	0.65	0.66	0.98	INEFF
11	0.87	0.87	1.00	INEFF	0.86	0.86	1.00	EFF	0.98	1.00	0.98	INEFF
12	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
13	0.95	0.95	0.99	INEFF	0.97	0.98	1.00	INEFF	0.88	0.88	1.00	INEFF
14	0.72	0.80	0.89	INEFF	0.73	0.80	0.91	INEFF	0.72	0.77	0.93	INEFF

15	0.76	0.77	1.00	INEFF	0.71	0.71	1.00	INEFF	0.60	0.62	0.97	INEFF
16	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
17	0.91	0.97	0.95	INEFF	0.83	0.93	0.89	INEFF	0.87	0.90	0.96	INEFF
18	0.93	0.95	0.98	INEFF	0.99	1.00	0.99	INEFF	1.00	1.00	1.00	EFF
19	1.00	1.00	1.00	EFF	0.95	1.00	0.95	INEFF	0.89	1.00	0.89	INEFF
20	0.82	0.83	0.99	INEFF	0.77	0.77	1.00	INEFF	0.71	0.71	1.00	INEFF
21	0.80	0.81	0.99	INEFF	0.84	0.84	1.00	INEFF	0.75	0.75	1.00	INEFF
22	0.74	0.75	0.98	INEFF	0.77	0.77	0.99	INEFF	1.00	1.00	1.00	EFF
23	1.00	1.00	1.00	EFF	0.68	0.69	0.99	INEFF	0.63	0.65	0.97	INEFF
24	0.83	0.84	0.99	INEFF	0.76	0.77	0.99	INEFF	0.58	0.68	0.85	INEFF
25	0.78	0.80	0.98	INEFF	0.75	0.76	0.99	INEFF	0.61	0.61	1.00	INEFF
26	0.97	1.00	0.97	INEFF	1.00	1.00	1.00	EFF	0.97	1.00	0.97	INEFF
27	0.78	0.78	0.99	INEFF	0.71	0.71	1.00	INEFF	0.66	0.66	1.00	INEFF
28	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
29	0.75	0.76	0.98	INEFF	0.76	0.76	1.00	INEFF	0.75	0.77	0.98	INEFF
30	0.80	0.84	0.95	INEFF	0.85	0.88	0.96	INEFF	0.86	0.87	0.99	INEFF
31	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
32	0.87	0.89	0.98	INEFF	0.75	0.76	0.99	INEFF	0.75	0.77	0.98	INEFF

Continued overleaf

Table 5: (*Continued*)

33	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
34	0.80	0.84	0.95	INEFF	0.76	0.78	0.97	INEFF	0.70	0.71	0.99	INEFF
35	0.72	0.76	0.95	INEFF	0.82	0.84	0.97	INEFF	0.63	0.65	0.98	INEFF
36	0.87	0.93	0.94	INEFF	0.82	0.92	0.89	INEFF	0.80	0.89	0.90	INEFF
37	0.86	0.87	0.99	INEFF	0.90	0.91	0.99	INEFF	0.93	0.95	0.98	INEFF
38	0.78	0.82	0.96	INEFF	0.77	0.78	0.98	INEFF	1.00	1.00	1.00	EFF
39	1.00	1.00	1.00	EFF	0.97	1.00	0.97	INEFF	0.85	0.90	0.95	INEFF
40	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF
41	0.74	0.78	0.96	INEFF	0.74	0.75	0.99	INEFF	0.69	0.69	1.00	INEFF
42	0.98	1.00	0.98	INEFF	0.99	1.00	0.99	INEFF	0.96	0.98	0.98	INEFF
43	0.78	0.80	0.98	INEFF	0.71	0.75	0.95	INEFF	0.69	0.69	1.00	INEFF
44	0.70	0.73	0.96	INEFF	0.66	0.68	0.97	INEFF	0.65	0.65	1.00	INEFF
45	0.89	1.00	0.89	INEFF	0.78	1.00	0.78	INEFF	0.78	1.00	0.78	INEFF
46	0.91	1.00	0.91	INEFF	1.00	1.00	1.00	EFF	1.00	1.00	1.00	INEFF
47	0.67	0.93	0.72	INEFF	0.73	1.00	0.73	INEFF	0.72	1.00	0.72	INEFF
48	0.81	1.00	0.81	INEFF	0.74	1.00	0.74	INEFF	0.72	1.00	0.72	INEFF
49	1.00	1.00	1.00	EFF	1.00	1.00	1.00	EFF	0.97	1.00	0.97	INEFF
Average	0.86	0.90	0.96	**Average**	0.85	0.89	0.96	**Average**	0.83	0.87	0.96	

Table 6: Return to Scale (RTS) of Each Company, 2008-2010

DMU	2008	2009	2010	DMU	2008	2009	2010
1	DRS	DRS	CRS	26	DRS	CRS	DRS
2	IRS	DRS	DRS	27	IRS	IRS	IRS
3	CRS	CRS	CRS	28	CRS	CRS	CRS
4	CRS	CRS	CRS	29	IRS	IRS	DRS
5	IRS	CRS	DRS	30	IRS	IRS	DRS
6	DRS	DRS	DRS	31	CRS	CRS	CRS
7	DRS	DRS	DRS	32	IRS	IRS	DRS
8	IRS	DRS	DRS	33	CRS	CRS	CRS
9	CRS	DRS	DRS	34	IRS	IRS	DRS
10	DRS	DRS	DRS	35	IRS	IRS	IRS
11	IRS	IRS	DRS	36	IRS	DRS	DRS
12	CRS	CRS	CRS	37	IRS	IRS	IRS
13	IRS	DRS	IRS	38	IRS	IRS	CRS
14	DRS	DRS	DRS	39	CRS	IRS	IRS
15	IRS	DRS	DRS	40	CRS	CRS	CRS
16	CRS	CRS	CRS	41	IRS	IRS	IRS
17	DRS	DRS	DRS	42	IRS	IRS	IRS
18	IRS	IRS	CRS	43	IRS	IRS	IRS
19	CRS	DRS	DRS	44	IRS	IRS	DRS
20	IRS	IRS	IRS	45	IRS	IRS	IRS
21	IRS	IRS	IRS	46	IRS	CRS	CRS
22	IRS	IRS	CRS	47	IRS	IRS	IRS
23	CRS	IRS	DRS	48	IRS	IRS	IRS
24	IRS	DRS	DRS	49	CRS	CRS	IRS
25	IRS	IRS	DRS				

Table 7: Percentage of Reduction Required in Observed Value of Inputs (Under CRS Assumption)

DMU	% Reduction in Input 2008				% Reduction in Input 2009				% Reduction in Input 2010			
	RM	**COE**	**PM**	**COGS**	**RM**	**COE**	**RM**	**COGS**	**RM**	**COE**	**RM**	**COGS**
1	28.4	67.0	61.0	28.4	8.5	8.5	8.5	8.5	-	-	-	-
2	20.1	20.1	57.3	20.1	5.9	5.9	37.9	5.9	30.2	30.2	53.3	30.2
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	6.8	6.8	39.6	6.8	-	-	-	-	24.3	24.3	24.3	24.3
6	14.7	14.7	56.8	14.7	15.3	15.3	15.3	15.3	11.5	11.5	11.5	11.5
7	32.5	20.8	20.8	20.8	45.0	26.0	26.0	26.0	46.2	33.0	33.0	33.0
8	31.4	31.4	54.2	31.4	9.7	9.7	22.0	9.7	4.4	4.4	53.0	4.4
9	-	-	-	-	23.5	23.5	45.5	23.5	32.2	32.2	32.2	32.2
10	40.5	22.1	22.1	22.1	37.6	27.3	27.3	27.3	35.4	35.4	35.4	35.4
11	75.4	13.4	13.4	13.4	14.1	14.1	14.1	14.1	62.7	1.9	1.9	1.9
12	-	-	-	-	-	-	-	-	-	-	-	-
13	5.2	5.2	54.5	5.2	2.7	2.7	26.7	2.7	12.2	12.2	12.2	12.2
14	48.1	28.4	28.4	28.4	27.1	27.1	27.1	27.1	30.0	28.4	28.4	28.4
15	32.7	23.8	23.8	23.8	55.2	29.1	29.1	29.1	40.5	40.5	40.5	40.5
16	-	-	-	-	-	-	-	-	-	-	-	-
17	47.5	8.6	8.6	8.6	42.6	17.5	17.5	17.5	13.5	13.5	13.5	13.5
18	6.9	6.9	15.3	6.9	1.5	1.5	32.8	1.5	-	-	-	-
19	-	-	-	-	5.5	5.5	5.5	10.8	47.8	11.3	11.3	11.3
20	18.3	18.3	42.2	18.3	22.9	22.9	22.9	22.9	29.5	29.5	29.5	29.5

Continued overleaf

Table 7: (*Continued*)

DMU	% Reduction in Input 2008				% Reduction in Input 2009				% Reduction in Input 2010			
	RM	**SE**	**PM**	**COGS**	**RM**	**SE**	**RM**	**COGS**	**RM**	**SE**	**RM**	**COGS**
21	20.2	20.2	40.5	20.2	16.0	16.0	16.0	16.0	25.3	25.3	25.3	25.3
22	33.6	26.1	26.1	26.1	23.3	23.3	23.3	23.3	-	-	-	-
23	-	-	-	-	38.8	32.1	32.1	32.1	37.1	37.1	37.1	37.1
24	17.1	17.1	37.9	17.1	23.6	23.6	23.6	23.6	42.1	64.9	76.0	42.1
25	70.0	21.7	21.7	21.7	78.4	25.5	25.5	25.5	73.5	38.8	38.8	38.8
26	17.1	3.3	3.3	3.3	-	-	-	-	11.0	3.5	3.5	3.5
27	24.7	22.5	22.5	22.5	29.5	29.5	29.5	29.5	33.6	33.6	33.6	33.6
28	-	-	-	-	-	-	-	-	-	-	-	-
29	42.1	24.9	24.9	24.9	24.1	24.1	24.1	24.1	24.7	24.7	24.7	24.7
30	58.2	20.2	20.2	20.2	59.5	15.1	15.1	15.1	42.7	13.6	13.6	13.6
31	-	-	-	-	-	-	-	-	-	-	-	-
32	72.6	13.3	13.3	13.3	86.7	25.0	25.0	25.0	84.9	24.9	24.9	24.9
33	-	-	-	-	-	-	-	-	-	-	-	-
34	58.3	19.9	19.9	19.9	75.9	23.7	23.7	23.7	61.3	30.2	30.2	30.2
35	27.9	27.9	53.6	27.9	19.6	18.4	18.4	18.4	36.9	36.9	36.9	36.9
36	66.3	25.7	12.9	12.9	31.2	29.4	18.3	18.3	25.7	75.1	19.8	19.8
37	14.4	14.4	14.4	15.8	10.1	10.1	10.1	10.1	6.8	6.8	6.8	12.1
38	68.9	21.8	21.8	21.8	68.8	23.3	23.3	23.3	-	-	-	-
39	-	-	-	-	3.5	15.3	3.5	5.4	14.8	23.3	48.7	14.8
40	-	-	-	-	-	-	-	-	-	-	-	-
41	45.8	25.8	25.8	25.8	30.9	25.8	25.8	25.8	31.5	31.5	31.5	31.5
42	2.3	2.3	2.3	5.6	1.4	1.4	1.4	9.4	4.5	4.5	4.5	4.5
43	21.8	21.8	48.4	21.8	28.7	28.7	28.7	28.7	31.3	31.3	31.3	31.3
44	63.6	29.7	29.7	29.7	54.8	33.9	33.9	33.9	45.2	34.7	34.7	34.7
45	11.4	11.4	11.4	11.4	21.8	21.8	21.8	21.8	22.0	22.0	22.0	22.0
46	8.9	8.9	8.9	8.9	-	-	-	-	-	-	-	-
47	33.0	87.4	73.5	33.0	27.4	27.4	52.2	27.4	27.8	27.8	55.3	27.8
48	28.8	19.4	19.4	19.4	26.1	26.1	38.8	26.1	27.9	27.9	27.9	27.9
49	-	-	-	-	-	-	-		3.0	45.1	64.5	12.3
Avg.	**33.8**	**21.5**	**29.2**	**18.7**	**29.7**	**19.9**	**23.6**	**19.7**	**31.5**	**26.9**	**29.8**	**23.8**

Note: RM = Raw materials, SE = Staff expenses, PM = Plant and machinery, COGS = Cost of goods sold.

Appendix 1

Descriptive Statistics of the Input and Output Variables (In TH USD)

Year	Statistics	RM	SE	PM	COGS	Net Sales	EAT
2008	Mean	15,714	14,078	64,517	85,847	119,214	10,211
	Std. Dev.	21,234	58,084	122,942	117,731	169,589	16,887
	Maximum	118,406	409,606	693,169	654,348	933,089	76,005
	Minimum	274	424	2,348	5,171	7,736	11
2009	Mean	10,883	6,163	56,076	73,633	102,221	8,183
	Std. Dev.	12,142	7,888	90,623	95,676	137,336	14,476
	Maximum	50,632	38,146	353,599	501,049	690,126	56,476
	Minimum	168	388	2,028	3,987	6,009	23
2010	Mean	14,205	6,108	52,224	66,233	92,364	8,237
	Std. Dev.	16,158	7,051	79,169	77,382	113,033	16,344
	Maximum	65,237	30,893	354,487	358,895	518,004	89,634
	Minimum	155	213	1,545	4,162	6,365	12
2008-2010	Mean	13,601	8,783	57,605	75,238	104,600	8,877
	Std. Dev.	16,931	34,060	98,775	97,984	141,353	15,854
	Maximum	118,406	409,606	693,169	654,348	933,089	89,634
	Minimum	155	213	1,545	3,987	6,009	11

Appendix 2

List of Companies and Abbreviations

NO	COMPANY	TICKER CODE	NO	COMPANY	TICKER CODE
1	ENGRO CORPORATION LIMITED	ENGRO	**26**	COLGATE-PALMOLIVE (PAKISTAN) LTD	COLG
2	D.G KHAN CEMENT LIMITED	DGKC	**27**	DIN TEXTILE MILLS LIMITED	DINT
3	FAUJI FERTILIZER BIN QASIM LIMITED	FFBL	**28**	HABIB SUGAR LIMITED	HABSM
4	PAKARAB FERTILIZER LIMITED	PFLTFC2	**29**	RUPALI POLYESTER LTD	RUPL
5	LUCKY CEMENT LIMITED	LUCK	**30**	PAKISTAN ENGINEERING COMPANY LIMITED	PECO
6	ICI PAKISTAN LTD	ICI	**31**	SEARLE PAKISTAN LIMITED	SEARL
7	SAPPHIRE TEXTILE MILLS LIMITED	SAPT	**32**	SUNRAYS TEXTILE MILLS LIMITED	SUTM
8	FAUJI CEMENT COMPANY LIMITED	FCCL	**33**	FEROZSONS LABORATORIES LIMITED	FEROZ
9	GUL AHMED TEXTILE MILLS LTD	GATM	**34**	GULISTAN SPINNING MILLS LIMITED	GUSM
10	NISHAT (CHUNIAN) LTD	NCL	**35**	THATTA CEMENT COMPANY LIMITED	THCCL
11	INTERNATIONAL INDUSTRIES LIMITED	INIL	**36**	HIGHNOON LABORATORIES LIMITED	HINOON
12	UNILEVER PAKISTAN LTD.	ULEVER	**37**	ATLAS BATTERY LIMITED	ATBA
13	SITARA CHEMICAL INDUSTRIES LTD	SITC	**38**	RELIANCE COTTON SPINNING MILLS LIMITED	RCML
14	MASOOD TEXTILE MILLS LIMITED	MSOT	**39**	MEHRAN SUGAR MILLS LIMITED	MRNS
15	QUETTA TEXTILE MILLS LIMITED	QUET	**40**	UNILEVER PAKISTAN FOODS LIMITED	UPFL
16	MILLAT TRACTORS LIMITED	MTL	**41**	BOLAN CASTINGS LIMITED	BCL
17	GHANI GLASS LIMITED	GHGL	**42**	NOON PAKISTAN LIMITED	NOPK
18	ARTISTIC DENIM MILLS LIMITED	ADMM	**43**	CRESCENT FIBRES LIMITED	CFL
19	RAFHAN MAIZE PRODUCTS COMPANY LIMITED	RMPL	**44**	N. P. SPINNING MILLS LIMITED	NPSM
20	SURAJ COTTON MILLS LIMITED	SURC	**45**	ASHFAQ TEXTILE MILLS LIMITED	ASHT
21	ITTEHAD CHEMICALS LIMITED	ICL	**46**	WAH NOBEL CHEMICALS LIMITED	WAHN
22	PAKISTAN CABLES LIMITED	PCAL	**47**	SANA INDUSTRIES LIMITED	SNAI
23	FAZAL TEXTILE MILLS LIMITED	FZTM	**48**	SHIELD CORPORATION LIMITED	SCL
24	AL-ABBAS SUGAR MILLS LIMITED	AABS	**49**	MIRZA SUGAR MILLS LIMITED	MZSM
25	HIRA TEXTILE MILLS LIMITED	HIRAT			