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Size and Operational Performance of Manufacturing Companies in Pakistan Using Data Envelopment Analysis

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Abstract:

The purpose of this paper is to employ Data Envelopment Analysis to evaluate the efficiency of 49 manufacturing companies in Pakistan over the period of 2008 to 2010. Three inputs variables (raw materials, staff expenses and plant and machinery) and two output variables are used (net sale and earnings after tax).This study uses Pearson correlation to indicate positive correlation between input and output variables and employed input approach of DEA model. Data is gathered from OSIRIS database and these companies are categorized under large-sized (assets above USD100 million), medium-sized (assets between USD30 million to USD100 million) and small-sized (asset under USD30 million). The results indicate that small-sized company has the highest relative efficiency compared to large and medium-sized company. In addition, the study finds that 2 large-sized companies, 3 medium-sized companies and 5 small-sized companies are operating under the most productive scale size (MPSS) throughout the three-year period.

Keywords: Data Envelopment Analysis (DEA), operational performance manufacturing companies, Pakistan

1. Introduction

The manufacturing sector has a great potential on promoting economic growth and competiveness in the country like Pakistan. It is one of the leading sectors in Pakistan. The sector has experienced the fluctuations over the years under different financial conditions. For example, it experienced the lowest growth in 2008 to 2009 as minus 7.7 and improved to 4.36 percent in 2009 to 2010 (Habib-ur-Rehman, 2009; Shah, 2011). The lack of demand from the domestic market caused depreciation in rupee and international demand was largely hit by global financial crises which caused the slower growth in the manufacturing sector. In terms of gross domestic product (GDP), the share of manufacturing sector rose in the last 10 years from 14.7 percent in 1999-2000 to 18.7 percent in 2010-11. On the other side, investment a "booster" of an economy, according to Shah (2011) has shown a decreasing trend from 2007 to 2011.

Performance is a quality of any company, achieved by valuable outcome such as higher returns. It can also be measured by the levels of efficiency and this can be analyzed by a variety of methods, such as the parametric (stochastic frontier analysis) and non parametric (data envelopment analysis). The management of any company would like to identify and eliminate the underlying causes of inefficiencies, thus helping their firms to gain competitive advantage, or at least, meet the challenges from others (Yang, 2006). In today's economically competitive world, good financial management is a key indicator of a corporation's performance. The present status of manufacturing sector in Pakistan suggests that efficiency is a main issue and play a significant role in economic improvement during the present scenario. The performance measurement of manufacturing is initially done by conventional method such as financial ratios. Later, performance is measured by various methods such as using DEA.

Indeed, efficiency is main aspect for companies and for investors as well. Therefore, the current study explicitly assesses the operational performance for manufacturing companies in Pakistan using DEA.

2. Literature review

Various studies have been done for performance analysis, using conventional methods such as financial ratios. Since conventional methods can only support single input-output, the new approach introduced by Charnes et al. (1978)

known as constant return to scale (CRS)-Data envelopment analysis. This model supports multi input-output data. Banker et al., (1984) further extended it to variable return to scale. Since then, it has been used extensively by various researchers in different fields of interests including manufacturing companies.

In the case of Pakistan only one study has been carried out considering Pakistani manufacturing sector by Musleh-ud-din et al., (2007). They investigated the technical efficiency of the large scale manufacturing using DEA approach by output-oriented model under CRS and variable return to scale (VRS) assumption. Data were collected from 101 industries for 1995 and 1996 and for 2000 to 2001. Input variables include capital, labour, industrial cost and non-industrial cost and output variables was contribution of GDP. Under 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. Under VRS, average efficiency score increased from 0.31 in first period to 0.49 in the second period. Later, Tahir and Memon, (2011) and Memon and Tahir (2011) adopted the approach to investigate the efficiency of top manufacturing companies in Pakistan.

Thakur (2005) evaluates the efficiency levels of state-owned electric utilities by CCR and BCC-DEA model. The CCR efficiency had a mean score of 68 percent with three (Decision Making Units (DMU's) on efficiency frontier and majority were below the average efficiency level. The results using BCC model showed that the average efficiency was 84 percent with 10 DMU's were considered efficient.

Abokaresh and Kamaruddin (2011) considered effect on efficiency of 21 Libyan manufacturing firms before and after privatization, from 200 to 2008. The pre and post-privatized effect suggested no significant difference in technical efficiency. Average technical efficiency of all firms in the years (before privatization) was 49.5 percent, whereas, after privatization it became 62.3 percent. In addition, state-owned firms improved only 9.3 percent after privatization and private firms increased only 15.3 percent after privatization, though in all conditions there was no significant effect.

Zhou et al., (2011) assumed similar technology on large and medium-sized enterprises from thirty provinces using both CRS and VRS for the period from 2006 to 2008. The decreasing trend of technical efficiency was found in three years. 2006 is considered as the most efficient year with 23.3 percent efficient firms. Mostly, scale inefficiencies (decreasing return to scale) were observed throughout the years. Hajiha and Ghilavi (2012) assessed efficiency of 100 Tehran stock exchange listed manufacturing companies from Iran. BCC output oriented model was used to measure efficiency in seven years (2004-2010). Among 100 companies, there were only 37 percent DMU's who appeared to be as fully efficient in 2010. Furthermore, 1st and 2nd DMU's were efficient throughout the entire period.

3. Methodology

3.1 Variable selection and data collection

Input-output variables have been selected on the basis of production process in companies and previous studies. In this study we use three input variables and two output variables. Input variables are raw materials, staff expenses and plant and machinery, while output variables are net sale and earnings after tax. **Table 1** presents the three input variables and two output variables that have been employed in previous research. Data for 49 manufacturing companies was gathered from OSIRIS database for the period 2008 to 2101. Companies are divided into three categories: large-sized, medium-sized and small-sized company. The size is measured by their total assets. Large-sized company are those companies having total assets above USD100 million, medium-sized having USD30 million to USD100 million by total assets whereas small companies are those companies having assets under USD30 million. There are 16 companies under large-sized, 16 companies are medium-sized and 17 companies are small-sized company. **Table 2** shows the descriptive statistics of the variables used. Pearson correlation is also used to indicate positive correlation between input and output variables as depicted in **Table 3.** As a requisite in DEA, the input and output variables should be positive correlated. It means that the input and output variables used in this study is appropriate as it satisfies the requisite of DEA.

3.2 Data Envelopment Analysis

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, $1 \le k \le s$. 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:

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

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

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

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:

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

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

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

$\lambda_r \ge 0$ $r = 1,..., s$

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

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

Where

θ = Efficiency of DMU

S_i^- = Slack variable which represents the input excess value,

S_j^+ = Surplus variable represents the output shortfall value,

ε = Non-Archimedean number which represents a very small constant,

λ_r = 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 Large-sized company

Table 4 shows the results for large-sized company. 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 output. As shown in Table 4, the results show that the average CRS efficiency of large-sized Pakistani manufacturing companies is 64 percent in 2008, 76 percent in 2009 and 78 percent in 2010. In 2008 and 2009, five companies have perfect relative efficiency whereas in 2010, 7 companies have perfect relative efficiency. Under pure technical efficiency (PTE), 7 companies are considered efficient in 2008 and 2010, while 5 companies are considered efficient in 2009. Two DMUs; FFBL and MTL are consistently efficient throughout the three-year period. As can be seen from the table, the main cause of inefficiency of large-sized company is scale inefficiency. In other words, ENGRO, PFLTFC2, FCCL, SITC, MSOT and QUET, should improve their scale efficiency.

4.2 Medium-sized company

Table 5 shows the results of efficiency scores for medium-sized company. The results show that the average CRS efficiency of medium-sized company is 68 percent in 2008, slightly increase to 74 percent in 2009 and fall again to 70 percent in 2010. Overall technical efficiency (OTE) results show that 5 companies in 2008, 4 companies in 2009 and 6 companies in 2010, have perfect relative efficiency. Under PTE, 6 companies are considered efficient in 2008 and 2009, while 7 companies are perfectly efficient in 2010. Three companies, RMPL, COLG and HABSM are consistently efficient throughout the three-year period. Similarly with the large-sized company, the cause of inefficiency is scale and these companies need to improve their scale efficiency.

4.3 Small-sized company

As for small-sized company, the results in **Table 6** show that the average OTE efficiency in 2008 is 75 percent, 78 percent in 2009 and 77 percent in 2010. The results also clearly show that, out of 17 small companies only f5 DMUs with ticker code MRNS, UPFL, NOPK, WAHN and MZSM maintain their efficiency throughout the three-year period. Over 71 percent companies had inefficient use of resources and need to reduce in size. From 2008 to 2010, the number of efficient companies under CCR and VRS models increased from 5 to 8, respectively.

4.4 Overall technical efficiency trend

Figure 1 depicts the results for OTE efficiency scores for large, medium and small-sized company during 2008 to 2010. In 2008, the OTE for large-sized company is 64 percent, medium-sized company is 68 percent and small-sized

company is 75 percent. In 2009, the OTE for large-sized company is 76 percent, 74 percent for medium-sized company and 78 percent for small-sized company. In 2010, the OTE for large-sized company is 78 percent, 70 percent for medium-sized company and 77 percent for small-sized company. As an overall, the figure clearly shows that small-sized company is relatively efficient (76 percent) than medium (71 percent) and large-sized company (73 percent) for 2008-2010. This is consistent to that found by Aggrey et al. (2010) and contradicts to that found by Lu and Hung (2010).

5. Conclusion

The objective of this paper is to use data envelopment analysis to evaluate the operational performance of large, medium and small-sized manufacturing companies in Pakistan for the period 2008 to 2010. The study uses three input variables, raw materials, staff expenses and plant and machinery and two output variables, net sale and earnings after tax. The Pearson correlation results show that the input and output variables used from 2008 to 2010 are positive and this indicates that the DEA analysis is appropriate as it satisfies the requisite of DEA.

The average OTE efficiency of large-sized company is from 64 percent to 78 percent from 2008 to 2010. This study finds that 2 companies have maximum efficiency score of 100 percent in 2008, 2009 and 2010. The results for the medium-sized company show that the average OTE is from 68 percent to 70 percent from 2008 to 2010 while the average OTE scores for small-sized company is 75 percent to 77 percent from 2008 to 2010. 10 companies are operating under the most productive scale size (MPSS) throughout the three-year period. The results also indicate the causes of inefficiency among manufacturing companies in Pakistan are scale rather than pure technical inefficiencies. Moreover, this study finds an interesting finding i.e. small-sized company are more efficient (76 percent) than large (73 percent) and medium-sized company (71 percent) for the three-year period, 2008-2010. The results of this study provide a valuable reference for manufacturing companies in Pakistan in terms of reviewing their efficiency levels. This would help them to achieve companies' performance

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Table 1: Input and output variables used in past studies

Variables	**References**
Input	
Raw Material	Mazumdar and Rajeev, 2009; Sharma, 2008; Ar and Baki, 2007; Singh, 2007; Wu, 2005.
Salary and wages	Mazumdar and Rajeev, 2009; Sharma, 2008.
Plant & Machinery	Hajiha and Ghilavi, 2012; Mazumdar and Rajeev, 2009; Singh, 2007; Ar and Baki, 2007.
Output	
Net Sales	Hajiha and Ghilavi, 2012; Abokaresh and Kamaruddin , 2011; Zhou et al., 2011 ; Sharma, S. 2008; Wang. 2008; Lin, et al., 2005.
Earnings after tax	Abokaresh and Kamaruddin , 2011; Ling and Kamil, 2010; Qian and Dawai, 2009.

Table 1 provides three input and two output variables used in previous studies and selected for current study.

Table 2: Descriptive Statistics of variables used, 2008-2010 in Th USD

		Y_1	Y_2	X_1	X_2	X_3
Large (16 companies)	Mean	242,597	21,492	30,455	21,017	146,612
	Std. Dev	176,645	22,552	19,658	57,972	134,345
	Minimum	44,562	255	6,540	782	4,979
	Maximum	933,089	89,634	118,406	409,606	693,169
Medium (16 companies)	Mean	56,637	4,456	8,655	3,789	22,244
	Std. Dev	33,787	4,879	6,983	2,773	10,216
	Minimum	15,186	12	1,001	681	3,283
	Maximum	162,322	21,443	30,853	15,922	45,298
Small (17 companies)	Mean	19,860	1,164	2,393	1,968	7,116
	Std. Dev	11,170	1,142	1,891	2,462	4,369
	Minimum	6,009	11	155	213	1,545
	Maximum	47,146	5,104	7,259	15,934	23,280
Note: Y_1= Net sale, Y_2= Earnings after tax, X_1= Raw material, X_2= Staff expenses and X_3= Plant and Machinery.						

Table 2 presents the descriptive statistics of the variables used in study for each size of companies.

Table 3: Pearson Correlation coefficient by size

Large	**RM**	**SE**	**PM**	**NS**	**EAT**
RM					
SE	.650				
PM	.707	.627			
NS	.527	.666	.650		
EAT	.573	.401	.567	.720	
Medium	**RM**	**SE**	**PM**	**NS**	**EAT**
RM					
SE	.148				
PM	.122	.146			
NS	.392	.527	.243		
EAT	.440	.481	.152	.879	
Small	**RM**	**SE**	**PM**	**NS**	**EAT**
RM					
SE	.177				
PM	.378	-.095			
NS	.333	.325	.233		
EAT	.080	.178	.029	.636	

Table 3 illustrates the Pearson correlation results for all the variables used. The results show that the input and output variables are positively correlated. It means that the input and output variables used in this study is appropriate as it satisfies the requisite of DEA.

Table 4: DEA results for large-sized company

		2008				2009				2010			
No.	**DMU**	**OTE**	**PTE**	**SE**	**RTS**	**OTE**	**PTE**	**SE**	**RTS**	**OTE**	**PTE**	**SE**	**RTS**
1	ENGRO	0.50	1	0.50	DRS	0.93	1	0.93	DRS	1	1	1	CRS
2	DGKC	0.38	0.40	0.95	IRS	0.59	0.61	0.97	DRS	0.59	0.65	0.90	DRS
3	FFBL	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
4	PFLTFC2	0.55	0.83	0.66	DRS	1	1	1	CRS	1	1	1	CRS
5	LUCK	0.52	0.52	1	IRS	1	1	1	CRS	0.75	0.83	0.90	DRS
6	ICI	1	1	1	CRS	0.86	0.92	0.94	IRS	1	1	1	CRS
7	SAPT	0.53	0.66	0.79	IRS	0.49	0.63	0.78	IRS	0.53	0.53	1	IRS
8	FCCL	0.28	0.84	0.33	IRS	0.73	1	0.73	IRS	1	1	1	CRS
9	GATM	1	1	1	CRS	0.63	0.85	0.75	IRS	0.44	0.66	0.66	IRS
10	NCL	0.38	0.44	0.85	IRS	0.45	0.55	0.82	IRS	0.52	0.54	0.97	IRS
11	INIL	0.28	0.45	0.64	IRS	0.79	0.88	0.89	IRS	1	1	1	CRS
12	ULEVER	1	1	1	CRS	1	1	1	CRS	0.87	1	0.87	DRS
13	SITC	0.71	1	0.71	IRS	0.66	1	0.66	IRS	0.81	1	0.81	IRS
14	MSOT	0.64	0.93	0.69	IRS	0.67	1	0.67	IRS	0.55	0.98	0.57	IRS
15	QUET	0.45	0.76	0.59	IRS	0.40	0.70	0.58	IRS	0.49	0.66	0.74	IRS
16	MTL	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
	Average	0.64	0.80	0.79		0.76	0.88	0.86		0.78	0.87	0.90	

Note: OTE = Overall technical efficiency, PTE = Pure technical efficiency, SE = Scale efficiency and RTS = Return to scale

Table 4 shows the efficiency scores for large-sized company for 2008-2010.

Table 5: DEA results for medium-sized company

		2008				2009				2010			
No.	**DMU**	**OTE**	**PTE**	**SE**	**RTS**	**OTE**	**PTE**	**SE**	**RTS**	**OTE**	**PTE**	**SE**	**RTS**
1	GHGL	0.67	0.68	0.99	DRS	0.66	0.67	0.98	IRS	0.85	1	0.85	DRS
2	ADMM	0.40	0.64	0.63	IRS	1	1	1	CRS	1	1	1	CRS
3	RMPL	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
4	SURC	0.50	0.52	0.96	DRS	0.61	0.62	0.98	DRS	0.46	0.51	0.89	DRS
5	ICL	0.29	0.46	0.64	IRS	0.56	0.58	0.95	IRS	0.44	0.53	0.84	IRS
6	PCAL	0.58	0.64	0.91	IRS	0.61	0.70	0.87	IRS	1	1	1	CRS
7	FZTM	1	1	1	CRS	0.54	0.63	0.85	IRS	0.39	0.46	0.85	IRS
8	AABS	0.67	0.68	0.99	IRS	0.44	0.48	0.91	IRS	0.33	0.40	0.82	IRS
9	HIRAT	0.44	0.50	0.87	IRS	0.62	0.72	0.87	IRS	0.31	0.41	0.76	IRS
10	COLG	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
11	DINT	0.40	0.42	0.96	IRS	0.50	0.53	0.94	IRS	0.38	0.40	0.94	IRS
12	HABSM	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
13	RUPL	0.53	0.55	0.96	IRS	0.78	0.82	0.96	IRS	0.59	0.64	0.92	DRS
14	PECO	0.77	1	0.77	IRS	0.84	1	0.84	IRS	0.94	1.00	0.94	IRS
15	SEARL	1	1	1	CRS	0.97	1	0.97	IRS	1	1	1	CRS
16	SUTM	0.67	0.85	0.79	IRS	0.73	0.88	0.83	IRS	0.50	0.66	0.76	IRS
	Average	0.68	0.75	0.90		0.74	0.79	0.93		0.70	0.75	0.91	

Note: OTE = Overall technical efficiency, PTE = Pure technical efficiency, SE = Scale efficiency and RTS = Return to scale

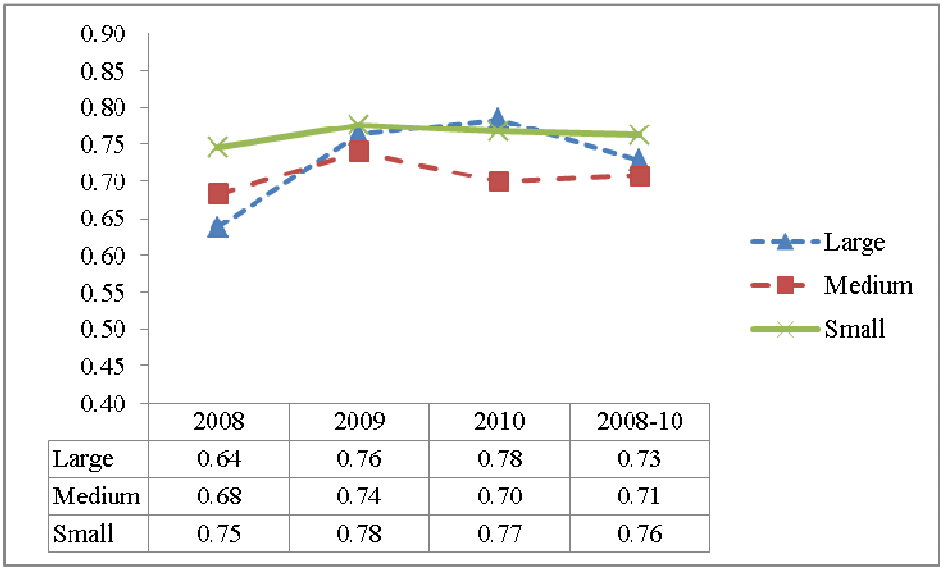
Table 5 shows the efficiency scores for medium-sized company for 2008-2010.

Table 6: DEA results for small-sized company

		2008				2009				2010			
No.	**DMU**	**OTE**	**PTE**	**SE**	**RTS**	**OTE**	**PTE**	**SE**	**RTS**	**OTE**	**PTE**	**SE**	**RTS**
1	FEROZ	0.75	0.80	0.94	IRS	1	1	1	CRS	1	1	1	CRS
2	GUSM	0.74	0.77	0.96	IRS	0.71	0.71	1	IRS	0.54	0.59	0.93	DRS
3	THCCL	0.44	0.49	0.91	IRS	0.74	1	0.74	DRS	0.49	0.50	1	IRS
4	HINOON	0.81	0.91	0.89	IRS	0.88	0.92	0.96	DRS	0.88	0.88	1	IRS
5	ATBA	0.89	0.89	1	DRS	1	1	1	CRS	1	1	1	CRS
6	RCML	0.57	0.57	1	DRS	0.56	0.67	0.83	DRS	1	1	1	CRS
7	MRNS	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
8	UPFL	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
9	BCL	0.68	0.73	0.94	IRS	0.78	0.78	1	IRS	0.54	0.56	0.96	DRS
10	NOPK	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
11	CFL	0.59	0.64	0.92	IRS	0.59	0.64	0.92	IRS	0.50	0.53	0.94	IRS
12	NPSM	0.58	0.61	0.96	IRS	0.51	0.51	1	IRS	0.46	0.49	0.94	DRS
13	ASHT	0.76	1	0.76	IRS	0.69	1	0.69	IRS	0.63	1	0.63	IRS
14	WAHN	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
15	SNAI	0.40	0.65	0.61	IRS	0.38	0.75	0.51	IRS	0.54	0.89	0.60	IRS
16	SCL	0.45	0.82	0.55	IRS	0.37	0.81	0.45	IRS	0.46	0.88	0.52	IRS
17	MZSM	1	1	1	CRS	1	1	1	CRS	1	1	1	CRS
	Average	0.75	0.82	0.91		0.78	0.87	0.89		0.77	0.84	0.91	

Note: OTE = Overall technical efficiency, PTE = Pure technical efficiency, SE = Scale efficiency and RTS = Return to scale

Table 6 shows the efficiency scores for small-sized company for 2008-2010.



	2008	2009	2010	2008-10
Large	0.64	0.76	0.78	0.73
Medium	0.68	0.74	0.70	0.71
Small	0.75	0.78	0.77	0.76

Figure 1: Overall efficiency trend

Figure 1 presents the pooled average overall efficiency trend of each size for 2008-2010.