The Pakistan Development Review
46 : 1 (Spring 2007) pp. 1–18

Technical Efficiency of Pakistan's Manufacturing Sector: A Stochastic Frontier and Data Envelopment Analysis

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This paper examines the efficiency of the large-scale manufacturing sector of Pakistan using parametric as well as non-parametric frontier techniques. Production frontiers are estimated for two periods─1995-96 and 2000-01─for 101 industries at the 5-digit PSIC. The results show that there has been some improvement in the efficiency of the large-scale manufacturing sector, though the magnitude of improvement remains small. The results are mixed at the disaggregated level: whereas a majority of industrial groups have gained in terms of technical efficiency, some industries have shown deterioration in their efficiency levels. The results from both the approaches are consistent, and in line with similar studies.

JEL Classification: D24, L6, O14, P27
Keywords: Manufacturing Industries, Technical Efficiency, Stochastic Frontier Analysis, Data Envelopment Analysis

1. INTRODUCTION

The large-scale manufacturing sector in Pakistan has gained increasing prominence over the years, with its share in output rising to about 13 percent in 2005-06 from 5.67 percent in 1959-60.[1] The sector has operated amid varying policy environments ranging from outright import substitution until the late 1980s to a more deregulated and liberal environment in the recent years (1990 onwards) driven largely by concerns to improve the efficiency of the industrial sector which is critical for attaining greater competitiveness. While industrial and trade policy reforms in recent years have exposed domestic enterprises to greater internal and external competition, most of these enterprises continue to seek state patronage and have yet to re-position themselves to compete effectively in the global market place. Furthermore, the trade policy still has an import substitution bias for certain critical sectors whose imports are subject to tariff peaks and this raises concerns on their efficiency.

This study aims to assess the technical efficiency of the large-scale manufacturing sector in Pakistan using two competing techniques i.e. the stochastic frontier analysis (SFA) and data envelopment analysis (DEA). The theoretical literature on technical efficiency can be traced back to Debreu (1951), Koopmans (1951), and Shephard (1953). Farrell (1957) introduced the concepts of cost efficiency and allocative efficiency,

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[1]Pakistan (Various Issues).

devised a method to decompose cost efficiency into allocative and technical components, and applied linear programming techniques to empirically measure technical efficiency. The underlying idea in Farrell's work is an efficient frontier against which the performance of productive units can be measured. Following these early works, many writers tried different techniques to estimate/compute the production frontier and efficiencies. Two such techniques[2] which have drawn wide attention from empirical researchers are (i) Stochastic Frontier Analysis (SFA), and (ii) Data Envelopment Analysis (DEA).

The SFA is an econometric technique introduced independently by Aigner, Lovell, and Schmidt (1977)[3] and Meeusen and Broeck (1977). Since the seminal work of Aigner, Lovell and Schmidt (1977) a growing body of literature has used the approach to estimate industrial efficiency in a variety of contexts. Taymaz and Saatci (1997) analyse the extent and importance of technical progress and efficiency in Turkish manufacturing industries. The rate and direction of technical change in three industries—textiles, cement, and motor vehicles—are estimated by using panel data on plants for the period 1987–92, using cobb-douglas, and translog stochastic frontier production functions. Ikhsan-Modjo (2006) examines the patterns of total factor productivity growth and technical efficiency changes in Indonesia's manufacturing industries over the period 1988–2000. The study uses the data incorporating both the liberalisation years and the crisis/post crisis years sourced from an annual panel survey of manufacturing establishments. Following the approach of Battese and Coelli (1995), a translog frontier production function is estimated.

Tripathy (2006) examines efficiency gap between foreign and domestic firms in eleven manufacturing industries of India during 1990–2000. Two different techniques, i.e. SFA and DEA are used to measure efficiency of the firms. The study assumes a Cobb-Douglas technology and estimates stochastic production and cost frontier in each industry to measure technical efficiency and cost efficiency of each firm as well as to obtain some inference on allocative efficiency. Alvarez and Crespi (2003) explore differences in technical efficiency in Chilean manufacturing firms. The authors use plant survey data and apply non-parametric frontier DEA that reveals significant inefficiencies with a large heterogeneity among sectors. Njikam (2003) assesses the effects of trade reform on firm-specific technical efficiencies in Cameroon manufacturing using firm-level balanced panel data that are used for the estimation of a Cobb-Douglas stochastic production frontier for each industrial sector.

The DEA, due to Charnes, Cooper, and Rhodes (1978), is a mathematical programming technique for the construction of a production frontier based on the notion of input oriented technical efficiency.[4] Some empirical studies have utilised the DEA to explore the question of industrial efficiency. Saranga and Phani (2004), based on a sample of 44 Indian pharmaceutical companies for the period 1992 to 2000 and using the

[2]These techniques may be used with input- or output-orientation. In the output-oriented measures of technical efficiency, outputs are maximised for a given levels of inputs, whereas in the input-oriented measures of technical efficiency, inputs are minimised for given levels of outputs.

[3]Battese and Corra (1977), using SFA, also appeared during the same year. This study is the first application of the SFA in which the technical inefficiency effects are found to be highly significant.

[4]Whereas this framework assumes constant returns to scale, Banker, Charnes, and Cooper (1984) extend this framework to allow for variable returns to scale.

DEA technique, investigate whether internal efficiencies have any role to play in the growth of companies in a constantly changing dynamic environmental context. Jajri and Ismail (2006) analyse trend of technical efficiency, technological change and TFP growth in the Malaysian manufacturing sector. The study uses DEA to calculate output-oriented Malmquist indices of Total Factor Productivity growth, technological change, and technical efficiency change. Lee and Kim (2006) analyse the effects of research and development (R&D) on Total Factor Productivity growth in manufacturing industries, using a sample of 14 OECD (Organisation for Economic Cooperation and Development) countries[5] for the years 1982–1993. With the assumption of constant returns to scale technology, the Malmquist Productivity Index and its components are computed using two traditional inputs i.e. labour and capital.

In the context of Pakistan's economy, Burki and Khan (2004) analyse the implications of allocative efficiency on resource allocation and energy substitutability. The study covers the period 1969-70 to 1990-91 and utilises pooled time series data from Pakistan's large-scale manufacturing sector to estimate a generalised translog cost function. The study also computes factor demand elasticities and elasticities of substitution by using the parameters of the estimated generalised cost function. The results indicate strong evidence of allocative inefficiency leading to over- or under-utilisation of resources and higher cost of production. Input-mix inefficiency takes the form of over-utilisation of raw material and capital *vis-à-vis* labour and energy. The study finds that allocative inefficiency of firms has on average decreased the demand for labour by 0.19 percent and increased the demand for energy by 0.12 percent. Own price elasticities of factors of production imply that the demand for capital is much more sensitive to its own price than the demand for labour. However, the elasticity of substitution between all factors is found out to be positive, which implies that they are substitutes. This is attributed to installation of new but more energy-efficient capital. The new machinery and plants, although more energy-intensive and raw material saving, leave the share of capital and labour unchanged.

The rest of the study is organised as follows. Section 2 sets out the methodology and discusses the data utilised in the study. Section 3 analyses the empirical findings, and Section 4 concludes the discussion.

2. METHODOLOGY AND DATA

This study utilises two competing techniques i.e. the SFA and DEA to estimate a production frontier which will serve as a benchmark to estimate the technical efficiencies of various industries. Whereas the SFA is based on parametric estimation, the DEA uses non-parametric linear programming technique. These competing techniques are based upon different sets of assumptions: SFA requires specific functional form and allows for random noise; the DEA does not require a specific functional form but ignores the random noise. Some studies, for example Banker, Gahd and Gorr (1993), report from a Monte Carlo experiment that the relative precision of DEA and SFA may be context specific. DEA might be the preferable technique where assumptions of typical

[5]The sample consists of Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Spain, United Kingdom, and United States.

neoclassical production theory are in question and measurement errors are unlikely. On the other hand, SFA has the advantage in handling measurement errors but functional form should closely match the properties of the underlying production technology. With this perspective it seems plausible that the analysis should be based upon alternative techniques to ensure robust conclusions.

Our approach is output-oriented, i.e. we seek to maximise output for a given level of inputs. The study covers 101 industries for the years 1995-96 and 2000-01. So, it is a comparative study of two cross-sections.

The Stochastic Production Frontier is assumed to be of Cobb-Douglas form with a composite error term:

$$\ln Y = \beta_0 + \beta_1 \ln K_i + \beta_2 \ln L_i + \beta_3 \ln IC_i + \beta_4 \ln NIC_i + v_i - u_i \qquad i = 1 \cdots\cdots n$$

Where: Y_i is output of the *i*th industry,

K_i is the amount of capital used in the *i*th industry,
L_i is the average number of persons engaged in the *i*th industry,
IC_i is the industrial cost in the *i*th industry,
NIC_i is the non-industrial cost in *i*th industry,
v_i is a component of the error term with normal distribution i.e. $v_i \sim N(0, \sigma_v^2)$
u_i is a component of error term with half-normal distribution[6] i.e. $u_i \sim N^+(0, \sigma_u^2)$
N is the total number of industries.

The symmetric error term v_i is the usual noise component to allow for random factors like measurement errors, weather, strikes etc. The non-negative error term u_i is the technical inefficiency component. The Ordinary Least Square estimation of the above model provides consistent estimates of β_i, but not of β_0. More importantly, we cannot obtain efficiency estimates through OLS [Kumbhakar and Lovell (2000)]. This issue is resolved by applying Maximum Likelihood estimation technique to obtain consistent parameter estimates as well as efficiency scores.[7]

Aigner, Lovell and Schmidt (1977) derived the likelihood function of the model based upon two parameters, $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda = \sigma_u / \sigma_v$ $(0 \leq \lambda \leq \infty)$. Battese and Corra (1977) replaced λ with $\gamma = \sigma_u^2 / \sigma_s^2$ $(0 \leq \gamma \leq 1)$. The latter parameterisation will be used in this paper.

The next step is to check the significance of inefficiencies estimated by the model, i.e., to test the null hypothesis of no inefficiencies against the alternative hypothesis that inefficiencies are present. As suggested by Coelli (1995), a one-sided likelihood ratio test with a mixed chi-square distribution ($\frac{1}{2}\chi_0^2 + \frac{1}{2}\chi_1^2$) is appropriate here. Therefore, the null hypotheses is rejected if $LR > \chi_1^2(2\alpha)$.

[6]Some writers have used different assumptions about distribution of u_i. Afriat (1972) assumes u_i to have a gamma distribution; Stevenson (1980) uses truncated normal distribution; and Greene (1990) uses two-parameter gamma distribution.

[7]The computer programme FRONTIER version 4.1, written by Coelli (1994) is used to obtain parameter estimates as well as the efficiency scores.

The DEA is an alternative technique for efficiency measurement and possesses certain advantages of its own. It can handle multiple outputs and multiple inputs stated in different measurement units and unlike SF it imposes no restrictions on the functional form. However, DEA has some limitations as well. Being a non-parametric technique, DEA is not amenable to direct application of tests of significance and statistical hypothesis testing, and statistical noise is not allowed for. We have applied DEA under two alternative assumptions[8]: constant returns to scale; and variable returns to scale.

The constant returns to scale model is attributed to Charnes, Cooper, and Rhodes (1978) and popularly known as CCR model. The following linear programming problem has been used to compute the efficiency scores:

$$\begin{aligned} &\min_{\theta,\lambda}\ \theta_i \\ \text{subject to}\quad & -y_{ip} + Y\lambda \geq 0 \\ & \theta_i x_{iq} - X\lambda \geq 0 \\ & \theta_i,\ \lambda_i \geq 0 \end{aligned}$$

Where, θ_i is the efficiency score for the *i*th industry, is an *nx* 1 vector of constants, *x* is a *p x n* input matrix, *y* is a *q x n* output matrix, and *n* is total number of industries.

The linear programming problem based upon constant returns to scale (CRS) assumption was modified by Banker, Charnes, and Cooper (1984) by imposing an additional convexity constraint , $e'\lambda = 1$. The variable returns to scale (VRS) frontier fits the data more closely; hence resulting efficiency scores are expected to be higher than those of CRS frontier. The VRS programme with additional convexity constraint is as follows:

$$\begin{aligned} &\min_{\theta,\lambda}\ \theta_i \\ \text{subject to}\quad & -y_{ip} + Y\lambda \geq 0 \\ & \theta_i x_{iq} - X\lambda \geq 0 \\ & e'\lambda = 1 \\ & \theta_i,\ \lambda_i \geq 0 \end{aligned}$$

Where *e* is a unit vector.

The data for the year 1995-96 are obtained from the Census of Manufacturing Industries (1995-96),[9] whereas data for 2000-01 are obtained from the summary tables prepared by the Federal Bureau of Statistics.[10] In all, 101 large-scale manufacturing industries are selected. There are 38 industries which have been excluded from the data set. Out of these 36 industries either do not have common industry codes or fall in some "other" category, and two industries, viz. Matches and Plastic Footwear have negative value added in the year 1995-96.

The following is a brief description of the variables:

[8]In this study we have used the programme EMS (Version 1.3) developed by Scheel (2000).
[9]This is the latest available published CMI.
[10]http://www.statpak.gov.pk/depts/fbs/statistics/manufacturing_industries/cmi_2001.html.

Output

CMI reports value added as well as contribution to GDP. Value added reported in CMI does not allow for non-industrial costs. So we have used contribution to GDP as output which equals value of production minus industrial cost minus net non-industrial cost.

Capital

Capital consists of land and building, plant and machinery and other fixed assets which are expected to have a productive life of more than one year and are in use by the establishment for the manufacturing activity.

Labour

Labour includes employees, working proprietors, unpaid family workers and home workers.

Industrial Cost

Industrial cost consists of cost of raw materials, fuels and electricity consumed, payments for work done, payments for repairs and maintenance and cost of goods purchased for resale.

Non-industrial Cost

Non-industrial cost consists of cost of payments for transport, insurance payments, copy rights and royalties, postage, telegraph and telephone charges, printing and stationery costs, legal and professional expenses, advertising and selling expenses, traveling expenses and other such expenses incurred by the establishment.

3. EMPIRICAL RESULTS

3.1. The Stochastic Frontier Technique

The model is estimated by maximum likelihood method for both the periods and the results are reported in Tables 1 and 2. All coefficients are statistically significant for both years except that of labour, which is insignificant for the year 2000-01. A possible explanation may be that the presence of rigidities in terms of worker lay off[11] may prevent firms from an optimal utilisation of the labour input which may become redundant owing to the adoption of more efficient technologies. That such technological developments have indeed taken place is corroborated by Burki and Khan (2004) who note that “traditional labour intensive technologies have gradually been replaced with more state-of-the-art efficient technologies”. The magnitude of the parameter gamma is 0.72 in 1995-96 and 0.64 in 2000-01; an indication that inefficiencies are the major component of the composite error terms in both the periods.

[11]Due perhaps to trade unions and strict labour laws, etc.

Table 1

Regression Results for the Year 1995-96

Variables	Coefficients	*t*-values
Constant	0.82	1.56*
Capital	0.18	2.30**
Labour	0.3	2.73**
Industrial Costs	0.36	3.42**
Non-industrial Costs	0.28	2.52**
Sigma-squared ($\sigma_s^2 = \sigma_u^2 + \sigma_v^2$)	0.96	4.20**
Gamma ($\gamma = \sigma_u^2 / \sigma_s^2$)	0.72	5.26**
LR Test of the One-sided Error = 4.2997		
With Number of Restrictions = 1		

*Significant at 0.10 level of significance.
** Significant at 0.01 level of significance.

Table 2

Regression Results for the Year 2000-01

Variables	Coefficients	*t*-values
Constant	0.26	0.53
Capital	0.36	5.19**
Labour	0.08	0.72
Industrial Costs	0.5	5.73**
Non-industrial Costs	0.1	1.54*
Sigma-squared ($\sigma_s^2 = \sigma_u^2 + \sigma_v^2$)	0.62	3.34**
Gamma ($\gamma = \sigma_u^2 / \sigma_s^2$)	0.64	2.92**
LR Test of the One-sided Error = 1.3446		
With Number of Restrictions = 1		

*Significant at 0.10 level of significance.
** Significant at 0.01 level of significance.

The likelihood ratio test of one-sided error gives a value of 4.3 for the year 1995-96 (significant at 0.05) and 1.3 for the year 2000-01 (significant at 0.125), implying that the use of stochastic frontier is justified.

Overall, the mean efficiency score increased from 0.58 in 1995-96 to 0.65 in 2000-01, indicating an improvement in efficiency of the large-scale manufacturing sector[12] (see Appendix for detailed efficiency scores). This increase in technical efficiency may be attributed to economic reforms initiated in the late 1980s aimed at improving competition and creating a better business climate for domestic and foreign investors. The market-oriented reforms opened up markets for imports and foreign investment, lowered administrative controls, and reduced government ownership. The reforms resulted in an increased role of market forces in resource allocation and this in turn helped improve the efficiency of most of the industrial sector. However, as the efficiency scores of the year

[12]It is important to note that the efficiency scores in each period measure technical efficiency in relation to the respective frontier in each period.

2000-01 indicate, there is still much room for improvement. If Pakistan is to become a competitive player in an increasingly globalised marketplace, efforts must focus on improvement of efficiency through enhanced competition, improved business processes, higher technology content of investment and well trained labour force. Strengthening of physical, financial and legal infrastructure will further contribute to efficiency of manufacturing industries.

The results are mixed at the disaggregated level. Table 3 reports the mean efficiency scores of various industries at the 3-digit level. In 1995-96, the top five industries in terms of their efficiency levels included tobacco manufacturing, petroleum refining, other non-metallic mineral products, other manufacturing, and electrical machinery and supplies. Among this group, while the level of efficiency of petroleum refining and electrical machinery and supplies improved marginally in 2000-01, the efficiency levels of tobacco manufacturing, other non-metallic mineral products, and other manufacturing declined.

The five least efficient industries turned out to be sports and athletic goods, surgical instruments, leather and leather products, manufacturing of textiles, and wearing apparel. Though all of these industries are export-oriented they continue to suffer from a variety of problems that may have hampered their efficiency.[13] For example, the surgical instruments industry largely produces low-end products using basic technology and very little effort has been made in moving towards higher value addition through better technology. The leather industry is mostly concentrated in the informal sector and is constrained by lack of training and poor technological base. The textiles group is the largest industrial sector in Pakistan. However, efficiency of this sector has been constrained by a variety of factors including low technological base, lack of adequately trained manpower, and little research and development to improve product and process technologies.

The situation is somewhat different in 2000-01, when sports and athletic goods, non-ferrous metals, and iron and steel made the top five efficient industries. Most remarkable is the turnaround shown by the sports and athletic goods, which earlier ranked among the least five efficient industries. Among the five least efficient industries are transport equipment, wearing apparel, glass and glass products, surgical instruments, and food manufacturing. It is noteworthy that the textiles and manufacturing are only marginally better off as compared with 1995-96, lying a notch above the five least efficient industries.

The efficiency scores of a diverse range of industries, including textile manufactures, food manufacturing, industrial chemicals, iron and steel, drugs and pharmaceutical products, electrical machinery and supplies, and non-electrical machinery, etc., indicate improvement in efficiency over time. It is important to note that while efficiency levels have improved, big gaps remain in terms of inefficiencies: for example, in 2000-01, the mean efficiency score ranged from 0.53 (transport equipment) to 0.87 (tobacco manufacturing). This implies that there is considerable room for improvement in the efficiency levels of these industries.

[13]The low level of efficiency of such industries probably explains why the government has all along provided a host of incentives to such export-oriented industries, i.e., to offset their inherent inefficiencies.

Table 3

Industry-wise Mean Efficiency Scores

	SF			DEA (CRS)			DEA (VRS)		
	1995-96	2000-01	%Change	1995-96	2000-01	%Change	1995-96	2000-01	%Change
Tobacco Manufacturing	0.88	0.87	–0.84	1.00	1.00	0.00	1.00	1.00	0.00
Petroleum Refining	0.74	0.76	3.70	1.00	1.00	0.00	1.00	1.00	0.00
Other Non-metallic Mineral Products	0.72	0.67	–6.39	0.39	0.33	–6.33	0.54	0.46	–8.73
Other Manufacturing	0.71	0.61	–14.14	0.40	0.46	14.82	0.76	0.48	–36.95
Electrical Machinery and Supplies	0.69	0.70	0.08	0.28	0.49	109.91	0.28	0.52	110.69
Pottery, China and Earthware	0.68	0.65	–2.40	0.26	0.25	3.89	0.29	0.30	8.82
Glass and Glass Products	0.66	0.56	–15.10	0.19	0.19	8.45	0.19	0.21	14.08
Industrial Chemicals	0.66	0.72	8.45	0.27	0.48	104.44	0.32	0.52	101.10
Other Chemical Products	0.66	0.64	–4.25	0.31	0.50	77.19	0.33	0.51	60.24
Printing and Publishing	0.66	0.73	24.33	0.34	0.45	201.13	0.35	0.48	205.89
Paper and Paper Products	0.65	0.66	2.19	0.25	0.30	36.61	0.25	0.41	92.51
Drugs and Pharmaceutical Products	0.63	0.67	8.76	0.20	0.43	112.95	0.38	0.55	45.11
Iron and Steel	0.60	0.75	25.34	0.42	0.69	63.35	0.49	1.00	103.13
Fabricated Metal Products	0.59	0.67	13.86	0.16	0.43	175.85	0.18	0.43	127.56
Rubber Products	0.57	0.73	30.25	0.17	0.56	413.31	0.45	0.65	108.51
Transport Equipment	0.56	0.53	–6.79	0.20	0.26	49.17	0.21	0.33	66.20
Food Manufacturing	0.56	0.58	16.11	0.25	0.37	206.77	0.33	0.44	161.85
Non-Ferrous Metal Industries	0.54	0.78	46.69	0.11	0.69	504.10	0.21	0.70	374.39
Non-electrical Machinery	0.49	0.62	30.61	0.14	0.31	167.86	0.15	0.34	137.35
Ginning and Baling of Fibre	0.48	0.73	51.30	0.23	0.94	307.77	0.23	0.94	307.68
Wearing Apparel	0.47	0.56	18.28	0.09	0.23	166.14	0.17	0.44	159.27
Manufacturing of Textiles	0.46	0.59	39.47	0.12	0.30	316.60	0.32	0.52	270.74
Leather and Leather Products	0.41	0.72	81.09	0.07	0.62	908.25	0.08	0.64	752.81
Surgical Instruments	0.30	0.58	90.44	0.04	0.16	300.22	0.04	0.16	293.87
Sports and Athletic Goods	0.30	0.77	154.58	0.06	0.66	1079.63	0.06	0.69	1132.21
Lime, Plaster and Manu. of Refractories	0.06	0.33	413.75	0.00	0.08	1733.51	0.02	0.10	462.69
Average (All Industries)	0.58	0.65	11.94	0.23	0.42	81.82	0.31	0.49	58.41

There has been a decline in efficiency of other non-metallic mineral products, tobacco manufacturing, transport equipment, other chemical products, pottery, china and earthenware, and glass and glass products. The highest decline is recorded by glass and glass products (15.10 percent) followed by transport equipment (6.79 percent), other non-metallic products (6.39 percent), other chemical products (4.25 percent), pottery, china and earthenware (2.4 percent) and tobacco manufacturing (0.84 percent). There may be several factors that may have caused a decline in the technical efficiency of such firms, not least the trade policy environment that may have shielded such industries from external competition.

3.2. Data Envelopment Analysis

In terms of the DEA, the efficiency scores have been computed under the assumptions of constant as well as variables returns to scale. With constant returns to scale, the mean efficiency score improved from 0.23 in 1995-96 to 0.42 in 2000-01. At the disaggregated level, results are largely similar to those derived under stochastic frontier: in 1995-96, the top five most efficient industries were tobacco manufacturing, petroleum refining, iron and steel, other manufacturing, and other non-metallic mineral products. Whereas tobacco manufacturing and petroleum manufacturing maintained their ranking in 2000-01, other sectors in this group were outranked by ginning and baling of fibre and non-ferrous metals industries which showed a remarkable improvement in their efficiency levels as compared with 1995-96. The five least efficient industries in 1995-96 were lime, plaster and manufacture of refractories, sports and athletic goods, surgical instruments, leather and leather products, and wearing apparel. Within this group, lime and plaster etc., surgical instruments, and wearing apparel remained at the lower end of efficiency scores in 2000-01 while the efficiency levels of pottery and earthenware and glass products declined so that these sectors made into the least efficient industries.

Under the assumption of variable returns to scale, the mean efficiency score increased from 0.31 in 1995-96 to 0.49 in 2000-01 showing an improvement in technical efficiency of the large-scale manufacturing sector. Looking at the industry level, the top five most efficient industries in 1995-96 were tobacco manufacturing, petroleum refining, other non-metallic mineral products, other manufacturing, and iron and steel. There was a significant improvement in the level of efficiency of non-ferrous metals, and ginning and baling of fibre enabling these industries to move into top five efficient industries in 2000-01. In terms of the five least efficient industries, the results are almost similar to the case of constant returns to scale.

A comparison of efficiency scores across techniques shows that on average, and in most of the cases efficiency scores using the stochastic frontier are higher than those obtained by using the data envelopment analysis. Within the data envelopment analysis, the efficiency scores are higher in case of variable returns to scale than those under the assumption of constant returns to scale. This is in line with the evidence suggested in the literature.[14] Overall there is a consistency of efficiency rankings which confirms that results are not sensitive to the technique used.

[14]See, for example, Lin and Tseng (2005).

4. CONCLUDING REMARKS

This paper has examined the efficiency of the large-scale manufacturing sector of Pakistan using two competing techniques, i.e., the Stochastic Frontier Analysis, and the Data Envelopment Analysis. The results on the basis of stochastic production frontier show that there has been some improvement in the efficiency of the large-scale manufacturing sector, though the magnitude of improvement remains small. The results are mixed at the disaggregated level: whereas a majority of industrial groups have gained in terms of technical efficiency, some industries have shown deterioration in their efficiency levels, including, for example, transport equipment, glass and glass products, other non-metallic mineral products, and other manufacturing. These findings are broadly supported by the Data Envelopment Analysis, lending a measure of robustness. Overall, the increase in technical efficiency may be attributed to economic reforms, initiated in the late 1980s, that were aimed at improving competition and creating a better business climate for domestic and foreign investors. The market-oriented reforms opened up markets for imports and foreign investment, deregulated markets, and reduced government ownership. The reforms resulted in an increased role of market forces in resource allocation and this in turn helped improve the efficiency of most of the industrial sector. However, there is still significant room for improvement especially as there has been a decline in the efficiency levels of some industries. If Pakistan is to become a competitive player in an increasingly globalised marketplace, efforts must focus on improvement of efficiency through enhanced competition, improved business processes, higher technology content of investment and well trained labour force. Strengthening of physical, financial, and legal infrastructure will further contribute to efficiency of the manufacturing industries.

APPENDIX

	SF			DEA (CRS)			DEA (VRS)		
	1995-96	2000-01	%Change	1995-96	2000-01	%Change	1995-96	2000-01	%Change
Manufacturing of Textiles									
Cotton spinning	0.39	0.57	47.6	0.12	0.2	68.03	1	1	0
Cotton weaving	0.43	0.48	11.5	0.1	0.13	35.81	0.37	0.43	15.68
Woollen textiles	0.59	0.66	11.3	0.22	0.38	70.47	0.22	0.4	80.98
Jute textiles	0.52	0.56	7.63	0.13	0.19	42.13	0.13	0.19	43.68
Silk and art silk textiles	0.49	0.62	28.25	0.21	0.29	37.6	0.28	0.61	118.22
Narrow fabrics	0.27	0.84	213.48	0.04	1	2536.42	0.04	1	2188.86
Finishing of textiles	0.38	0.5	33.08	0.08	0.19	146.47	0.14	0.28	94.44
Made up textile goods	0.44	0.48	8.6	0.11	0.13	23.05	0.11	0.14	24.53
Knitting mills	0.33	0.54	62.39	0.05	0.2	326.38	0.08	0.3	274.89
Cordage, rope and twine	0.61	0.61	–0.86	0.15	0.25	60.13	1	1	0
Spooling and thread ball making	0.57	0.63	11.16	0.13	0.32	136.11	0.14	0.32	136.82
Average (Group 1)	**0.46**	**0.59**	**39.47**	**0.12**	**0.3**	**316.6**	**0.32**	**0.52**	**270.74**
Food Manufacturing									
Dairy products	0.56	0.51	–8.82	0.22	0.21	–5.71	0.23	0.21	–6.76
Ice cream	0.6	0.78	29.46	0.18	0.53	201.38	0.19	0.53	186.04
Canning of fruits & vegetables	0.63	0.8	26.01	0.13	0.64	405.77	0.14	0.64	363.94
Canning of fish & sea food	0.48	0.42	–11.97	0.21	0.45	111.92	0.25	0.46	80.26
Vegetable Ghee	0.54	0.78	45.64	0.17	1	480.23	0.2	1	406.42
Cotton seed and inedible animal oils	0.59	0.56	–4.75	0.18	0.37	104.88	0.18	0.37	105.12
Rice milling	0.41	0.53	29.23	0.06	0.19	230.28	0.06	0.21	261.49
Wheat & grain milling	0.19	0.58	209.63	0.04	0.47	1227.53	0.05	0.47	804.68
Grain milled products and other grain milling	0.75	0.69	–8.23	0.37	0.32	–13.07	0.46	0.41	–9.36
Bread & bakery products	0.5	0.67	34.74	0.08	0.44	439.03	0.08	0.44	431.03
Biscuits	0.52	0.6	14.91	0.14	0.22	59.21	0.14	0.22	61.37
Refined sugar	0.64	0.65	0.73	0.32	0.34	6.09	1	1	0
Confectionery, not sweetmeats	0.64	0.44	–31.22	0.14	0.12	–11.05	0.15	0.13	–17.92
"Desi" sweetmeats and confectionery	0.72	0.37	–48.52	0.37	0.09	–74.91	1	0.09	–90.73
Blending of tea	0.71	0.49	–31.35	0.86	0.28	–67.93	0.93	0.28	–70.51
Feeds for animals	0.51	0.77	52.13	0.07	0.74	941.16	0.11	0.76	601

Continued—

Appendix Table—(*Continued)*

Feeds for fowls	0.23	0.45	97.86	0.07	0.22	207.62	0.08	0.23	191.55
Starch	0.71	0.69	–3.4	0.3	0.33	9.33	0.31	0.33	4.87
Edible salt	0.8	0.72	–9.52	1	0.43	–56.85	1	1	0
Ice	0.45	0.18	–60.29	0.08	0.03	–59.59	0.12	0.04	–65.58
Average (Group 2)	**0.56**	**0.58**	**16.11**	**0.25**	**0.37**	**206.77**	**0.33**	**0.44**	**161.85**
Industrial Chemicals									
Alkalies	0.6	0.72	20.12	0.14	0.31	124.08	0.14	0.33	130.75
Acids, salts & intermediates	0.63	0.76	21.34	0.16	0.55	248.28	0.17	0.57	241.47
Sulphuric acid	0.68	0.57	–16.63	0.19	0.19	1.43	0.23	0.19	–15.37
Dyes, colours & pigments	0.7	0.76	8.77	0.19	0.6	209.98	0.2	0.63	218.96
Compressed gases, etc.	0.61	0.7	15.48	0.14	0.31	118.5	0.15	0.32	113.99
Fertilizers	0.69	0.73	5.69	0.47	0.43	–7.91	0.75	0.66	–12
Pesticides, insecticides, etc.	0.67	0.79	18.08	0.38	0.85	122.84	0.39	0.86	117.85
Synthetic resins, etc.	0.74	0.7	–5.28	0.49	0.57	18.28	0.51	0.58	13.18
Average (Group 3)	**0.66**	**0.72**	**8.45**	**0.27**	**0.48**	**104.44**	**0.32**	**0.52**	**101.1**
Other Non-metallic Mineral Products									
Bricks & tiles	0.63	0.64	1.6	0.2	0.25	26.15	0.2	0.25	25.78
Cement	0.73	0.72	–1.35	0.45	0.45	–0.08	0.87	0.83	–4.92
Cement products	0.79	0.64	–19.43	0.52	0.29	–45.05	0.54	0.29	–47.06
Average (Group 4)	**0.72**	**0.67**	**–6.39**	**0.39**	**0.33**	**–6.33**	**0.54**	**0.46**	**–8.73**
Tobacco Manufacturing									
Cigarettes	**0.88**	**0.87**	**–0.84**	**1**	**1**	**0**	**1**	**1**	**0**
Iron and Steel									
Iron & steel mills	**0.6**	**0.75**	**25.34**	**0.42**	**0.69**	**63.35**	**0.49**	**1**	**103.13**
Medicines & basic drugs(allopathic)	0.54	0.74	36.17	0.16	0.55	249.96	0.51	0.87	70.79
"Unani" medicines	0.68	0.77	12.6	0.29	0.64	118.6	0.29	0.65	119.96
Homeopathic and other medicinal preparation	0.67	0.52	–22.5	0.16	0.12	–29.71	0.33	0.15	–55.41
Average (Group 7)	**0.63**	**0.67**	**8.76**	**0.2**	**0.43**	**112.95**	**0.38**	**0.55**	**45.11**
Electrical Machinary and Supplies									
Electrical industrial machinery	0.7	0.67	–4.43	0.25	0.26	2.37	0.25	0.26	3.78
Radio & television commu	0.77	0.73	–5.11	0.45	0.59	`	0.45	0.62	38.47
Electrical appliances	0.76	0.81	7.18	0.37	0.85	131.63	0.38	0.9	135.98

Continued—

Appendix Table—(*Continued)*

Insulated wires & cables	0.75	0.71	–5.96	0.33	0.37	13.33	0.33	0.4	23.06
Electrical bulbs & tubes	0.5	0.48	–3.16	0.07	0.24	233.8	0.08	0.25	208.76
Batteries	0.69	0.77	11.97	0.19	0.65	247.17	0.19	0.66	254.08
Average (Group 8)	**0.69**	**0.7**	**0.08**	**0.28**	**0.49**	**109.91**	**0.28**	**0.52**	**110.69**
Transport Equipment									
Motor vehicles	0.6	0.63	5.2	0.37	0.31	–15.26	0.4	0.53	33.37
Motor cycles, auto rickshaws	0.47	0.35	–25.62	0.09	0.08	–9.94	0.09	0.08	–7.59
Cycles & pedicabs	0.62	0.62	0.04	0.14	0.39	172.71	0.14	0.39	172.82
Average (Group 9)	**0.56**	**0.53**	**–6.79**	**0.2**	**0.26**	**49.17**	**0.21**	**0.33**	**66.2**
Other Chemical Products									
Paints, varnishes & lacquers	0.74	0.67	–8.46	0.43	0.49	13.92	0.45	0.5	9.33
Perfumes & cosmetics	0.67	0.66	–0.91	0.3	0.43	43.54	0.32	0.44	39.14
Soap & detergents	0.76	0.71	–7.49	0.5	0.7	38.55	0.51	0.71	38.61
Polishes & waxes	0.72	0.78	8.42	0.28	0.8	181.55	0.33	0.8	142.3
Ink (all kinds)	0.4	0.35	–12.84	0.05	0.1	108.37	0.06	0.1	71.8
Average (Group 10)	**0.66**	**0.64**	**–4.25**	**0.31**	**0.5**	**77.19**	**0.33**	**0.51**	**60.24**
Non-electrical Machinery									
Engines & turbines	0.37	0.56	49.62	0.04	0.17	324.39	0.07	0.2	181.99
Agricultural machinery	0.51	0.63	24.1	0.13	0.43	229.79	0.13	0.44	233.59
Metal & wood working machinery	0.45	0.66	47.33	0.24	0.43	79.85	0.25	0.44	80.04
Textile machinery	0.62	0.62	1.38	0.15	0.21	37.42	0.17	0.26	53.8
Average (Group 11)	**0.49**	**0.62**	**30.61**	**0.14**	**0.31**	**167.86**	**0.15**	**0.34**	**137.35**
Printing and Publishing									
Newspapers	0.76	0.76	0.53	0.36	0.61	71.86	0.36	0.66	80.42
Books, periodicals, maps, etc.	0.35	0.73	109.95	0.05	0.46	757.34	0.05	0.47	754.54
Job printing	0.83	0.75	–9.52	0.71	0.47	–34.2	0.71	0.48	–33.38
Printed cards & stationery	0.68	0.66	–3.62	0.24	0.26	9.49	0.27	0.33	21.99
Average (Group 12)	**0.66**	**0.73**	**24.33**	**0.34**	**0.45**	**201.13**	**0.35**	**0.48**	**205.89**
Petroleum Refining									
Petroleum refining and products of petroleum & coal	**0.74**	**0.76**	**3.7**	**1**	**1**	**0**	**1**	**1**	**0**
Paper and Paper Products									
Pulp & paper	0.64	0.7	8.76	0.17	0.38	119.74	0.17	0.59	244.01

Continued—

Appendix Table—(*Continued)*

Paperboard	0.59	0.69	16.01	0.24	0.29	22.93	0.24	0.32	34.41
Pulp, paper & board articles	0.7	0.57	–18.19	0.33	0.22	–32.83	0.33	0.32	–0.89
Average (Group 14)	**0.65**	**0.66**	**2.19**	**0.25**	**0.3**	**36.61**	**0.25**	**0.41**	**92.51**
Wearing Apparel									
Ready-made garments	**0.47**	**0.56**	**18.28**	**0.09**	**0.23**	**166.14**	**0.17**	**0.44**	**159.27**
Leather and Leather Products									
Tanning and leather finishing	0.41	0.7	70.51	0.08	0.57	623.64	0.09	0.59	538.63
Leather products excepts footwear	0.31	0.68	120.32	0.03	0.4	1260.97	0.04	0.41	853.65
Leather foot-wear	0.5	0.77	52.42	0.09	0.89	840.14	0.1	0.92	866.17
Average (Group 16)	**0.41**	**0.72**	**81.09**	**0.07**	**0.62**	**908.25**	**0.08**	**0.64**	**752.81**
Ginning and Baling of Fibre									
Ginning (Cotton and others)	**0.48**	**0.73**	**51.3**	**0.23**	**0.94**	**307.77**	**0.23**	**0.94**	**307.68**
Rubber Products									
Tyres & tubes	0.7	0.79	13.36	0.21	0.87	310.7	0.22	0.9	316.2
Retreading tyres & tubes	0.53	0.72	37.3	0.07	0.65	782.39	1	1	0
Rubber foot-wear	0.57	0.71	25.63	0.37	0.32	–12.19	0.43	0.34	–22.05
Vulcanized rubber products	0.59	0.71	19.84	0.13	0.46	245.33	0.14	0.47	237.35
Rubber belting	0.45	0.7	55.13	0.06	0.51	740.32	0.47	0.53	11.08
Average (Group 18)	**0.57**	**0.73**	**30.25**	**0.17**	**0.56**	**413.31**	**0.45**	**0.65**	**108.51**
Pottery, China and Earthware									
China & ceramics	0.6	0.68	13.22	0.2	0.25	26.12	0.2	0.26	25.19
Earthenware and other pottery	0.76	0.62	–18.01	0.31	0.26	–18.34	0.38	0.35	–7.56
Average (Group 19)	**0.68**	**0.65**	**–2.4**	**0.26**	**0.25**	**3.89**	**0.29**	**0.3**	**8.82**
Glass and Glass Products									
Glass	0.69	0.5	–27.78	0.23	0.16	–31.97	0.23	0.19	–20.34
Glass products	0.64	0.63	–2.42	0.15	0.22	48.86	0.15	0.22	48.49
Average (Group 20)	**0.66**	**0.56**	**–15.1**	**0.19**	**0.19**	**8.45**	**0.19**	**0.21**	**14.08**
Non-ferrous Metal Industries									
Aluminium & aluminium alloys	0.49	0.84	72.84	0.12	1	764.05	0.12	1	717.34
Copper & copper alloys	0.59	0.71	20.55	0.11	0.38	244.15	0.3	0.39	31.44
Average (Group 21)	**0.54**	**0.78**	**46.69**	**0.11**	**0.69**	**504.1**	**0.21**	**0.7**	**374.39**

Continued—

Appendix Table—(*Continued*)

Fabricated Metal Products									
Cutlery	0.52	0.6	15.21	0.06	0.25	325.9	0.09	0.25	195.09
Structural metal products	0.57	0.67	16.93	0.14	0.24	68.09	0.17	0.27	59.79
Metal stamping, coating, etc.	0.6	0.85	40.94	0.24	1	310.8	0.29	1	242.56
Heating & cooking equipment	0.69	0.84	21.06	0.18	1	464.31	0.26	1	278.61
Wire product	0.47	0.46	–1.06	0.1	0.14	43	0.1	0.14	40.74
Utensils - aluminium	0.7	0.64	–9.35	0.26	0.31	20.31	0.26	0.31	19.59
Tin cans & tinware	0.71	0.61	–13.2	0.21	0.24	15.01	0.21	0.24	16.36
Metal trunks and bolts, nuts, rivets, etc.	0.48	0.68	40.34	0.09	0.23	159.38	0.09	0.24	167.74
Average (Group 22)	**0.59**	**0.67**	**13.86**	**0.16**	**0.43**	**175.85**	**0.18**	**0.43**	**127.56**
Surgical Instruments									
Surgical instruments	**0.3**	**0.58**	**90.44**	**0.04**	**0.16**	**300.22**	**0.04**	**0.16**	**293.87**
Sports and Athletic Goods									
Sports & athletic goods	**0.3**	**0.77**	**154.58**	**0.06**	**0.66**	**1079.63**	**0.06**	**0.69**	**1132.21**
Lime, Plaster, and Manufacture of Refractories									
Lime, plaster and manufacture of refractories	**0.06**	**0.33**	**413.75**	**0**	**0.08**	**1733.51**	**0.02**	**0.1**	**462.69**
Other Manufacturing									
Bone crushing	0.71	0.61	–14.14	0.4	0.46	**14.82**	0.76	0.48	**–36.95**
Average (All Industries)	**0.58**	**0.65**	**11.94**	**0.23**	**0.42**	**81.82**	**0.31**	**0.49**	**58.41**

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