Performance of Industrial Establishments in Northwest Bangladesh: A Stochastic Frontier Analysis

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Abstract

The performance of industrial establishments in northwest Bangladesh in terms of employment, output and value added generation is assend in the paper by applying the stochastic frontier model. Research results show there are no remarkable number of large and medium industries except some small and cottage industries like, rice milling, bidi manufacturing industries, and wooden furniture manufacturing industries. Results also reveal that the average levels of performance of industrial establishments in this region are lower Than the national aneage. Stochastic frontier results reveal that efficiency performance of industries in this region is 86 and 90 per cent and that of industries in Bangladesh is 90 and 98 per cent for the period 1991 – 1992 and 1999 – 2000, respectively that indicates performance of industries in this region is lower than that of industries in Bangladesh for both periods. Therefore there is room for obtaining production gain through improvement of efficiency of industries without resort to technological progress. This result also implies that production gain can be obtained from 2 to 10 per cent through improvement of efficiency performance of industries. Given the level of technical efficiency of industries, The paper suggests introduction of new technologies and improvement of existing level of technologies that could provide technically optimal level of industrialization in northwest Bangladesh and improve the performance of industries, employment and income generation.

1. Introduction

The northwest Bangladesh can be broadly classified as greater Dinajpur district consisting of districts - Panchagarh, Thakurgaon, Dinajpur, and greater Rangpur

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This is a revised part of a research entitled 'Industrialization in Northwest Bangladesh' conducted by the author in 2007-2008 funded by RDRS Bangladesh.

district consisting of districts - Nilphamari, Rangpur, Kurigram, Lalmonirhat, and Gaibandha. This northwest region is mainly characterized as agro-based economy and poverty-ridden with surplus low-cost labour. Some parts of this region are affected by ***monga*** with no job and no purchasing power during particular times in the year. This means that there are many unemployed people and/or labour directly and indirectly and it becomes difficult for them to maintain livelihood during off peak times in a year. This labour force can be utilized in other sectors like industry with appropriate training. Many people migrate to Dhaka, Rajshahi and other cities to maintain their livelihood.

There is an EPZ in Nilphamari district, northwest Bangladesh, among 8 EPZs in Bangladesh. This EPZ is established with a view to achieving employment, income, and hence reducing poverty through setting up industries and utilizing benefits of land ports and airport and the Jamuna Bridge.

There are four land ports located in the borders of the northwest districts among fourteen land ports in Bangladesh. Trade between Bangladesh and India, Bangladesh and Nepal, Bangladesh and Bhutan, and perhaps betwen Bangladesh and China can be done with special terms and conditions. The benefits of the land ports situated in this region can be used to the process of industrialization. The construction of Jamuna Multi-purpose Bridge has facilitated the transportation infrastructure, which is one of the important preconditions for industrial development. With this infrastructural facility, low-cost labour input supply and other materials, industrialization along with agriculture should be developed properly to solve unemployment problem, alleviate poverty and have sustainable livelihood. Therefore it is worthwhile to assess the performance of industrial establishments along with the status of number of industries in this region for effective industrialization.

For predicting the potentiality of effective industrialization, a performance evaluation, that is, productivity performance assessment of industries is of utmost importace. Productivity advancement can be obtained through technological improvement and efficiency advancement, which industries have achieved. Technological advancement involves the introduction of new inputs like machinery, new production techniques, etc. Efficiency enhancement implies the improvement of capability of an industry so that it best utilizes available resources to produce maximum levels of potential outputs. Thus it implies the ability of the producers to utilize the factor inputs properly. Ability can be improved through training, learning by doing, etc. Variations in output among industries can be explained through differences in technology and efficiency.

Therefore productive performance of an industry has technical change and efficiency improvement component. With a view to quantifing and estimating the efficiency component of productive performance of industries, we apply stochastic econometric frontier model. This will give an estimate of how much output could be increased if inputs and material, which are in the production process, were utilized properly in a cost-efficient way. These results provide performance of the industries that will lead to suggestions for technically optimum industrialization in this area. The objective of this paper is to evaluate the performance of industrial establishments in this region with a comparison of performance of industrial establishments in Bangladesh as a whole.

This paper is organized as follows. Section 2 gives an account of industrial establishments in this region; Section 3 highlighto the performance of industrial establishments along with national values. Section 4 describes theoretical issues of measuring efficiency performance of industries, theoretical and empirical framework; Section 5 details results of efficiency performance of industries; Section 6 concludes the paper.

2. Accounts of Industrial Establishments in Northwest Bangladesh

A detailed account of number of sector-wise and district-wise industrial establishments of northwest districts is persented has we also present an account of persons engaged, industrial costs, performance of industries in terms of gross output and value added of industries in northwest districts. and compare their average values with national average. Data have been collected from two sources - *Report on Bangladesh Census of Manufacturing Industries, 1991-92 (Bangladesh Bureau of Statistics, 1997) and 1999-2000 (Bangladesh Bureau of Statistics, 2004).*

2.1. Product-and District-wise Industrial Establishment and their Performances

2.1.1. Product-and District Industrial Establishment, 1991 - 1992

We need to have an account of product or sector wise industrial establishments to find which industrial establishments are working and which are not. This will help find reasons for not industries not working set up policies for action. Table 1 shows the number of sector-wise industrial establishments located in the northwest districts in Bangladesh. It is constructed based on information given in Report on Bangladesh Census of Manufacturing Industries (CMI) 1991 – 1992, Bangladesh Bureau of Statistics, 1997. Table 1 shows that, except Lalmonirhat and Gaibandha, all other northwest districts have the highest number of rice milling establishments. Dinajpur has the highest number of rice milling establishments followed by Thakurgaon. According to this Census, Saw and Planing Mills establishments stand second in number in the northwest districts. Dinajpur has the highest number of industrial establishments followed by Rangpur. Lalmonirhat has the lower number of industrial establishments.

Table 1 also shows that this region does not possess those sorts of industries which employ huge number of labour and hence flourish industrialization. Neither fertilizer nor power industry is recorded in this region by this Census. Majority of establishments are rice milling establishments which do not run the entire year and do not give sustainable employment of labourers. Except some bakery, there is no agro-based or food processing industry recorded. This implies that this region is a neglected region and is excluded from mainstream development of the country.

2.1.2. Industrial Establishment, 1999-2000

Table 2 is prepared based on information contained in Report on Bangladesh Census of Manufacturing Industries (CMI) 1999-2000, Bangladesh Bureau of Statistics, 2004. It also shows number of industrial establishments arranged sector-wise in northwest districts during this period. Table 2 exhibits that the largest number of industrial establishments is located in Dinajpur district followed by Rangpur and Thakurgaon and the lowest number of establishments is located in Nilphamari district. According to this census report, Dinajpur has the largest number of rice milling industrial establishments followed by Rangpur and Thakurgaon. Among all districts, Rangpur has the highest number of Bricks, Tiles and Clay Products establishments and bidi manufacturing establishments.

This Census does not record any fertilizer and power industries, although this region possesses an agrarian economy and require huge amount of fertilizer, and power is the de riving is the deriving force of industries and modern agriculture. In spite of a labour force surplus region, according to the Census, there is no readymade garments industry recorded which is known to be labour-intensive in nature.

Rice milling, Bidi manufacturing, wooden furniture manufacturing, Bricks, Tiles and Clay manufacturing establishments are main industrial establishments. Most of these establishments are small and cottage industries in nature. Some industries

Table 1 : Sector-wise Industrial Establishment of Northwest Bangladesh,1991-1992

Sl. No.	No of Establishments	Panch agarh	Thaku rgaon	Dina jpur	Nilph amari	Rang pur	Kuri gra m	Lalm onirh at	Gai ban dha	Total
1	Agricultural Machenary Equipment					1				1
2	Allopathic and Medicines			1						1
3	Ayure-Vedic Medicines			1		1				2
4	Bakery Products			28		7				35
5	Bidies Manufacturing			1		63		7	3	74
6	Bolts, Nuts and Rivets			7		14				21
7	Bricks, Tiles, Clay Products	1	1	7	1	9	4		1	24
8	Cotton Textiles			1	1					2
9	Dist. Rectified Spirits	1				1				2
10	Electrical Apparatus	14				1				15
11	Furniture and Fixtures			28						28
12	Grain Milling			1						1
13	Hydrigebated Vegetable Oil					1				1
14	Iron and Steel Foundries					1				1
15	Jewellery, Precious Metals							14		14
16	Jute pressing and Baling			1						1
17	Jute Textiles	1								1
18	Manufacturings of Earthenwares								57	57
19	Metal, Trunks Manufacrurings								3	3
20	Misc. Food Products			14						14
21	Polythene Products Manufacturing					3				3
22	Printing of Book, Map etc.			14						14
23	Railroad Equipment Manufacturing				1					1
24	Readymade Garments							1		1
25	Rice Milling	28	60	473	28	47	28			664
26	Saw and Planing Mills		28	28	28	28				112
27	Silk, Synthetic Textiles		1	1		7				9
28	Structural Products of Bamboo					1				1
29	Sugar Factory					1			1	2
30	Tobacoo Steww, Redrying				3	4				7
31	Tobacoo Manufacturing N.E.C.				1					1
32	Wood, Bamboo Handicrafts	1								1
33	Wooden Furniture Manufacturings		28			14				42
Total		46	118	606	63	204	32	22	65	1156

Source: Bangladesh Bureau of Statistics, 1997, Report on Bangladesh Census of Manufacturing Industries (CMI) 1991-92.

Table 2 : Sector-wise Industrial Establishment of Northwest Bangladesh, 1999-2000

Sl. No.	No of Establishments	Panchagarh	Thakurgaon	Dinajpur	Nilphamari	Rangpur	Kurigram	Lalmonirhat	Gaibandha	Total
1	Agricultural Machenary Equipment					1				1
2	Allopathic and Medicines									
3	Ayure-Vedic Medicines									
4	Bakery Products					16				16
5	Bidies Manufacturing			4		68	6	6	8	92
6	Bolts, Nuts, Rivets and Wash			10						10
7	Bricks, Tiles, Clay Products		21	21		84	22			148
8	Cotton Textiles except hand loom	8		1			2			11
9	Dist. Rectified Spirits					2				2
10	Electrical Apparatus					2				2
11	Furnitures and Fixtures									
12	Grain Milling									
13	Hydrigebated Vegetable Oil									
14	Iron and Steel Foundries									
15	Jewellery, Precious Metals									
16	Jute pressing and Baling									
17	Jute Textiles									
18	Manufacturings of Earthenwares								27	27
19	Metal, Trunks Manufacrurings									
20	Misc. Food Products (other food)			30						30
21	Polythene Products Manufacturing					15				15
22	Printing of Book, Map etc.									
23	Railroad Equipment Manufacturing									
24	Readymade Garments									
25	Rice Milling	2	88	555		92	43			780
26	Saw and Planing Mills					40				40
27	Silk, Synthetic Textiles									
28	Structural Products of Bamboo					2				2
29	Sugar Factory	2		2						4
30	Tobacoo Stemming, Redrying				2	33				35
31	Tobacoo Manufacturing N.E.C.				7					7
32	Wood, Bamboo Handicrafts									
33	Wooden Furniture Manufacturings		120							120
34	Cigarette Manufacturing					2				2
35	Mfg. of soap and detergents					10				10
36	Manufacture of Knitwear		1							1
37	Mfg of cutleries			8						8
Total		12	230	631	9	367	73	6	35	196

39Source: Bangladesh Bureau of Statistics, 2004. Report on Bangladesh Census of Manufacturing Industries, 1999-2000, Bangladesh Bureau of Statistics, 2004.

like Rice milling, Bricks manufacturing do not provide employment doing the entire year. This happens perhaps because there were no effective policies and steps to industrialization from government or private or non-government institutions.

3. Performance of Industrial Establishments

3.1. Performance of Industrial Establishments, 1991 - 1992

In general, the growth of the industrial sector in the northwest Bangladesh is constrained by the lack of infrastructure, low entrepreneurship knowledge and facility, credit facilities, technology, capital, corruption, lack of political commitment, political instability, etc. The industrial policies of Bangladesh have not given any particular emphasis on the industrial development in this area. A picture of performance of industrial sector is inevitable to provide policy suggestions to the policy makers.

Table 3 – 5 analyze status and performance of industrial establishments prevailing in northwest districts in Bangladesh in terms of employment, assets, gross output and value added. Table 3 specifically provides number of establishment, persons

Table 3 : Status of the Industrial Establishment, 1991 – 1992

Districts	No of Establishment	% of Establishment	No. of Persons engaged	% of Persons Engaged
Panchagarh	46	0.17	5858	0.45
Thakurgaon	118	0.45	1802	0.14
Dinajpur	606	2.29	13715	1.05
Nilphamari	63	0.24	6518	0.50
Rangpur	204	0.77	21103	1.62
Kurigram	32	0.12	608	0.05
Lalmonirhat	22	0.08	3418	0.26
Gaibandha	65	0.25	3047	0.23
Total	1156	4.37	56069	4.30
Average	145		7009	
Rajshahi Div.	7765	29.36	222128	17.03
Average	485		13883	
Bangladesh	26446	100.00	1304397	100.00
Average	413		20381	

Source: Bangladesh Census of Manufacturing Industries, 1991– 92. Bangladesh Bureau of engaged and presents a comparison of establishments of northwest region with those of Bangladesh on an average basis. This table is drawn based on the information given in the Report on Bangladesh Census of Manufacturing Industries, 1991-92. It shows that the average number of industrial establishment in northwest districts is 145 whereas the national average is 413 industries. This implies that average number of establishments in the northwest region is less than a half of the national average. These eight districts possess only 4.37 percent of industrial establishments. This table also tells that the average employment in eight districts is 7009 that is slightly above one-third of the national average of employment of 20381 persons. This indicates that this region employs only 4.30 percent of persons engaged in all industrial establishments in Bangladesh.

Assets, input cost, gross output and value added of industrial establishments are shown in Tables 4 and 5. Assets and input cost of industrial establishments show the bigness of these establishments(Table 4). Assets also contribute to improvement of output of industries. Total fixed asset of industrial establishments in northwest districts are Tk. 4414758 thousands whereas in Bangladesh it is Tk. 102415191 thousands. Thus the ratio of assets of northwest industrial establishments to total assets of Bangladesh industrial establishments a of 1991-1992 in 1:23 (BBS, 1997).

The picture of gross output, value added of industries based on *Report on Bangladesh Census of Manufacturing industries, 1991-1992* is pasintd in Table 5

Table 4 : Assets, Wages and Costs of Industrial Establishments, 1991 – 1992

	Fixed Assets	Wages, salaries and others	Input cost	Non-industrial cost and indirect tax
Panchagarh	912377	131406	357655	33538
Thakurgaon	44785	20603	189234	2015
Dinajpur	691951	150413	1515321	16495
Nilphamari	2246405	169183	191344	7350
Rangpur	485462	192532	835457	178891
Kurigram	4998	4898	124026	573
Lalmonirhat	2206	4224	10581	4073
Gaibandha	26574	60973	193658	80850
Total	4414758	734232	3417276	323785
Average	551844.8	91779	427159.5	40473.13
Bangladesh	102415191	27654856	149618561	22158633
National average	1600237	432107.1	2337790	346228.6

Source: Report on Bangladesh Census of Manufacturing Industries, 1991-1992. Bangladesh Bureau of Statistics. 1997. Figures are in thousands taka.

Gross output, value added of industries indicate the magnitude and strength of industrial establishments. The table gives an average estimate of gross output of industries in 8 northwest 8 districts of Tk. 614896 thousands and an average estimate of gross output of industries in Bangladesh of Tk. 3482307 thousand. The shows hat average gross output of northwest districts is snst about 17 persent of that of 64 districts in Bangladesh. We get an almost similar picture for gross value added and value added at factor cost. (about 16 to 18 persnt of national average).

Table 5: Gross Output, Value Added of Industrial Establishments, 1991 – 1992

	Gross output	Gross Value Added	Value added at factor cost
Panchagarh	450322	92667	59129
Thakurgaon	214662	25428	23413
Dinajpur	1897958	382637	366142
Nilphamari	398034	206690	199340
Rangpur	1516719	681262	502371
Kurigram	131519	7493	6920
Lalmonirhat	22431	11850	7777
Gaibandha	287523	93865	13015
Total	4919168	1501892	1178107
Average	614896	187736.5	147263.4
Bangladesh	222867636	73249075	51090442
National average	3482307	1144517	798288.2

Source: Report on Bangladesh Census of Manufacturing Industries, 1991-1992, Bangladesh Bureau of Statistics, 1997.

3.2. Performance of Industrial Establishments, 1999 – 2000

Table 6 provides the status of industrial establishments based on the information contained in Report on Bangladesh Census of Manufacturing Industries, 1999-2000. This table shows that although the average number of industrial establishments has increased, the average number of employment has gone down to about a half. The northwest districts employ only 2.2 percent of employed people in 1999-2000 as against 4.3 percent in 1991-1992. While the national average of industrial establishments has gone down from 413 in 1991-1992 to 386.75 in 1999-2000, average employment has gone up from 20381 to 40836.94 persons. This implies that national average employment has gone double almost.

Assets and cost information of industrial establishments in northwest districts along with their national averages are given in Table 7 which is constructed based

Table 6 : Status of the Industrial Establishments, 1999-2000

Districts	No of Establishment	% of Establishment	No of Person Engaged	% of Persons Engaged
Panchagarh	12	0.05	2932	0.11
Thakurgaon	230	0.93	6133	0.23
Dinajpur	631	2.55	22341	0.85
Nilphamari	9	0.04	259	0.01
Rangpur	367	1.48	20798	0.80
Kurigram	73	0.29	3522	0.13
Lalmonirhat	6	0.02	327	0.01
Gaibandha	35	0.14	1275	0.05
Total	1363	5.51	57587	2.20
Average	170.375		3599.188	
Rajahshi	6569	26.54	348161	13.32
Average	410.56	1.66		
Bangladesh	24752	100	2613564	100
Average	386.75		40836.94	

Source: Bangladesh Census of Manufacturing Industries. 1999– 2000, Bangladesh Bureau of Statistics, 2004.

on information contained in *Reports on Bangladesh Census of Manufacturing Industries, 1999-2000*. Average fixed asset of industries in northwest districts is Tk.292486.5 thousands whereas average fixed asset in Bangladesh districts is

Table 7 : Assets and Cost of Industrial Establishments, 1999 - 2000

	Fixed Assets	Wages, salaries and others	Input cost	Non-industrial cost and indirect tax
Panchagarh	191646	643389	446681	78115
Thakurgaon	108983	134136	1591726	68200
Dinajpur	1545352	446146	2703886	103776
Nilphamari	7199	2800	13163	455
Rangpur	278954	250489	771832	303516
Kurigram	200632	62353	43195	10237
Lalmonirhat	4633	2556	4858	5242
Gaibandha	2493	6553	14185	15160
Total	2339892	1548422	5589526	584701
Average	292486.5	193552.75	698690.75	73087.63
Bangladesh	243804966	72284450	403777567	79622999
National Average	3809452.60	1129444.531	6309024.484	1244109

Source: Report on Bangladesh Census of Manufacturing Industries. 1999-2000. Bangladesh Bureau of Statistics, 2004.

Tk.3809452.60 thousands which is more than 13-fold larger. Table 7 also reveals that although average asset is 13-fold larger the average input cost is 9-fold greater than the value of average input cost of northwest districts in Bangladesh.

Table 8 gives an account of gross output and value added of industrial establishments in northwest districts based on information given in Report on *Bangladesh Census of Manufacturing Industries, 1999-2000*. It also provides an estimate of national averages of gross output and value added. It shows that where average gross output of industries in Bangladesh is tk.9987818.45 thousands, the average gross output of industries in the northwest is tk.968677.50 thousands which is 10-fold lower than that of national average. Similarly, average gross value added in northwest district is more than 13-fold lower than that of national average of Bangladesh. This definitely expresses the lower output and income generation capacity of industrial establishments in northwest Bangladesh.

Table 8: Gross Output and Value Added of Industrial Establishments, 1999 - 2000

	Gross output	Gross Value Added	Value added at factor cost
Panchagarh	765102	318422	240307
Thakurgaon	1903649	311923	243722
Dinajpur	3457475	753589	649813
Nilphamari	17816	4653	4198
Rangpur	1463031	691198	387682
Kurigram	89392	46197	35961
Lalmonirhat	13644	8786	3543
Gaibandha	39311	25127	9967
Total	7749420	2159895	1575193
Average	968677.50	269986.88	196899.13
Bangladesh	639220381	235442813	155819815
National Average	9987818.45	3678793.95	2434684.61

Source: Bangladesh Bureau of Statistics, 2004. Report on Bangladesh Census of Manufacturing Industries, 1999-2000. Values are in thousand taka.

3.3. Comparison of Performance among Northwest with Administrative Division

Table 9 provides a comparative statistics of the number of establishments, persons engaged, gross output and value of northwest districts with administrative divisions in Bangladesh. Table shows that 16 districts of Rajshahi division possess 6570 industrial establishments. Among this, 8 northwest districts possess only 1363 establishments, which are about one-fifth of industrial establishments in Rajshahi division. Although the number of establishments in Chittagong division is smaller than Rajshahi division, total persons employed, gross output and gross value added in Chittagong division are much greater than Rajshahi division. Even Sylhet division has only 404 establishments which are about one-third of industrial establishments in northwest districts, yet gross output and value added of establishments of this division are greater than those of northwest districts. It is evident from this table that employment and income generation capacity of industrial establishments in northwest districts are lower than those of other divisions.

Table 9 : No. of Establishments, Persons Engaged, Gross Output and Value Added by Administrative Divisions

	No of Establishment	Total Persons Engaged	Gross Output	Gross Value Added	Value Added Factor Cost
Chittagong	3831	492229	124027	48979	38229
Dhaka	11588	1566379	438247	163420	102336
Khulna	2314	146316	32278	10487	5553
Rajshahi	6570	348161	35636	9437	7422
Barisal	45	6622	661	359	173
Sylhet	404	53858	8372	2761	2107
Northwest Bangladesh	1363	57587	7749.42	2159.90	1575
Bangladesh	24752	2613564	639220	235443	155820

Source: Bangladesh Bureau of Statistics, 2004. Report on Bangladesh Census of Manufacturing Industries, 1999-2000. Output and value added are in million taka.

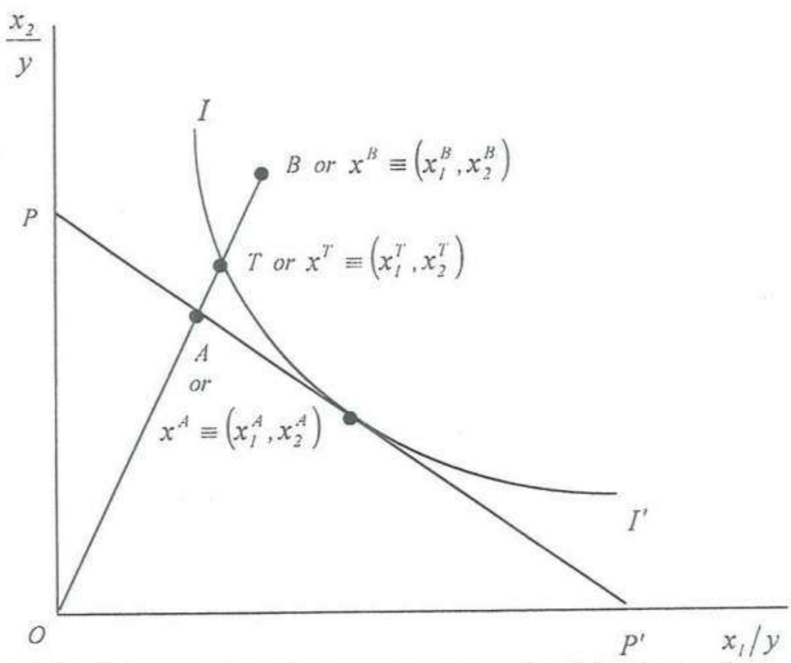
4. Efficiency Performance of Industrial Establishments

4.1. Defining Efficiency

The measurement of efficiency begins with Farrell (1957). The failure to produce the maximum output from a given input mix at minimum cost results in inefficiency. Technical efficiency concerns the ability of an industry to produce maximum output from a given set of inputs using existing technology. To explain diagrammatically the concept of technical efficiency, consider the production activity of an industry, following Kopp and Diewert (1982). In Figure 1, assume that the industry uses two inputs and to produce a single output y, and that the production technology is summarized by a linearly homogeneous production function following Farrell. The frontier unit isoquant for this technology and an inefficient production activity are depicted by and respectively. Along the ray , the

the production activity, denoted by T and defined by the intersection of line segment OB with the isoquant II', represents a technically efficient input combination as it lies on the frontier isoquant. The technical inefficiency of the industry producing at point B is represented by the distance TB because this is the amount by which both inputs could be proportionally reduced producing the same level of output. In percentage terms, this is usually written as the ratio TB/OB.

Figure 1: Measures of Technical Efficiency



The technical efficiency of the industry operating at point B is expressed as:

$$TE = \frac{OT}{OB} = 1 - \frac{TB}{OB} = 1 \text{ - Technical inefficiency} \quad (0 \le TE \le 1).$$

The industry operating at point T is fully technically efficient industry because it is located on the efficient and frontier isoquant and $TE = 1$.

4.2. Theoretical Framework: The Stochastic Frontier Analysis

This section aims to specify the empirical framework for this research project with a comprehensive review of literature. The seminal paper of Farrell (1957) on efficiency pioneered the development of different approaches to efficiency measurement. The general stochastic frontier production function model, independently proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), decomposes the composed error term into two components: a stochastic random error component and a technical inefficiency component. The stochastic approach attempts to distinguish the effects of stochastic noise from the effects of inefficiency. Addressing the stochastic noise problem associated with the deterministic frontier, and statistical hypothesis testing are the main strengths of the stochastic frontier approach; assumptions regarding the parametric functional form for the frontier technology and the distributional assumptions for the technical inefficiency term are its major drawbacks. Comprehensive reviews of the various stochastic frontier functions and econometric estimation of frontiers are provided also by Førsund et al. (1980), Schmidt (1986), Bauer (1990), Battese (1992), Bravo-Ureta and Pinheiro (1993), Greene (1993) and Coelli (1995).

We use one-stage formulation of estimation methodology which specifies the technical inefficiency effects (Kumbhakar et al., 1991) and estimates the stochastic frontier and the inefficiency effects simultaneously, given appropriate distributional assumptions (Battese and Coelli, 1995). The simultaneous estimation of the stochastic production frontiers and models of technical inefficiency using maximum likelihood techniques has been proposed by Kumbhakar et al. (1991), Huang and Liu (1994), Battese and Coelli (1995). This one-stage approach is statistically consistent and leads to more efficient inference with respect to the parameters (Coelli and Battese, 1996). The approach has been applied empirically by, among others, Coelli and Battese (1996), Coelli (1996), Battese and Broca (1997), Ajibefun et al. (1996), Seyoum et al. (1998), Wadud and White (2000) and Wadud (2003).

The general stochastic frontier production model is defined as:

$$y_i = f(x_i;\beta)e^{u_i} \qquad (1)$$
$$u_i = \xi_i - \zeta_i,\ \ i = 1,2,3,....q, \qquad -\infty \le \xi_i \le \infty \text{ and } \zeta_i \ge 0.$$

where y_i represents the output of the ith industry, x_i denotes a vector of q inputs, and β denotes the parameters. The error term, u_i, is decomposed into a stochastic random disturbance and an asymmetric non-negative random error term. The stochastic random disturbances, ξ_i, the symmetric random errors, take account of measurement error and capture exogenous shocks and other factors not under the control of the industries; The asymmetric non-negative random errors, ζ_i, which are called technical inefficiency effects, account for technical inefficiency in production. When $\zeta_i = 0$, the production function is the best-practice frontier, which yields the maximum output given the inputs; and when $\zeta_i > 0$, output is less than this maximum due to technical inefficiency. The greater the quantity by which the actual output falls short of the stochastic frontier output, the higher the level of technical inefficiency. The observed differences in output can be attributed to either technical inefficiency or stochastic disturbances or both. A model without ζ_i is the average frontier model criticized by Farrell (1957).

Assuming a probability density function for both ξ_i and ζ_i, we can estimate (1) by maximum likelihood methods. This approach yields a means by which we can statistically examine the sources of differences between the industry's output and the frontier output by calculating the variance parameters which relate the variance of ξ_i to the composed variance of u_i (Kalirajan, 1981).

The variance parameters are expressed as:

$$\sigma_u^2 = \sigma_\xi{}^2 + \sigma_\zeta{}^2, \qquad \gamma = \sigma_\zeta^2 / \sigma_u^2 \ \text{ and } 0 \le \gamma \le 1 \tag{2}$$

If $\gamma \to 0$ then $\sigma_\zeta^2 \to 0$ and $\sigma_\xi^2 \to \sigma_u^2$, which implies that the symmetric error term ξ_i dominates the composed error term and output differs from the frontier output mainly due to measurement errors and the effect of other external factors on production. If $\gamma \to 1$ then $\sigma_\xi^2 \to 0$ and $\sigma_\zeta^2 \to \sigma_u^2$ which indicates that the asymmetric non-negative error term ζ_i dominates the composed error and the differences between output and frontier output can be attributed to differences in technical efficiency.

The technical efficiency of the ith industry is defined as the ratio of the observed output to the corresponding frontier output, given the levels of the inputs. The industry-specific technical efficiency, φ_i, can be measured as:

$$\varphi_i = \frac{y_i}{y_i^*} = \frac{f(x_i,\beta)e^{(\xi_i-\zeta_i)}}{f(x_i,\beta)e^{\xi_i}} = e^{-\zeta_i} \qquad 0 \le \varphi_i \le 1$$

The systematic random error, ξ_i, is assumed to be independently and identically distributed with mean zero and variance, σ_ξ^2; and ζ_i are non-negative truncations of the $N(\mu, \sigma_\zeta^2)$ distribution. Measurements of the industry-specific efficiency, $e^{-\zeta_i}$, depends upon the decomposition of u_i, which is derived from the conditional expectation of $e^{-\zeta_i}$ given u_i. Thus the technical efficiency of each industry is given by

$$\therefore \quad \varphi_i = \left[\frac{1-\Phi\left\{\sigma_i^* - \left(\mu_i^*/\sigma_i^*\right)\right\}}{1-\Phi\left(-\mu_i^*/\sigma_i^*\right)}\right] e^{\left(-\mu_i^* + \frac{1}{2}\sigma_i^{*2}\right)} \tag{4}$$

which produces the measure of technical efficiency given the specification of the frontier production function model and the inefficiency effects model. Technical inefficiency is estimated by $1 - E\left\{e^{-\zeta_i}|u_i\right\}$. The mean technical efficiency of all industries in the sample, $\overline{\varphi}$, is obtained as:

$$\overline{\varphi} = \left[\frac{1-\Phi\left\{\sigma^* - \left(\mu^*/\sigma^*\right)\right\}}{1-\Phi\left(-\mu^*/\sigma^*\right)}\right] e^{\left(-\mu^* + \frac{1}{2}\sigma^{*2}\right)}.$$

This methodology calculates the maximum likelihood estimator of the predictor for the technical efficiency that is based on the conditional expectation of $e^{-\zeta_i}$ given the composed error term of the stochastic frontier production model (Battese and Coelli, 1988). The parameters of the coefficients of stochastic frontier model, β, and the technical inefficiency effects model, δ_i, along with the variance parameters are also estimated.

The principal drawbacks of this approach are assumptions about the distributions of technical inefficiency and the random term and the nonexistence of an *a priori* justification of choosing the distributional form of the random noise (Coelli, 1995).

4.3. Empirical Methodology: The Cobb-Douglas Stochastic Frontier

Several specifications of the production function, e.g., Cobb-Douglas, translog, etc. have been applied. The Cobb-Douglas production function has been widely used in econometric analysis. We use the Cobb-Douglas production approach in our analysis:

$$\ln y_i = \beta_0 + \sum^{q} \beta_i \ln x_i + u_i \qquad (5)$$

where y_i = gross output of industry i, β_0 is an "efficiency parameter", i.e., an indicator of the state of technology, x_1 =wages and salaries, x_2 = ten percent value of fixed assets, x_3 = value of materials, x_4 = non-industrial cost and indirect tax and ln = natural logarithm, β_i $(i = 1,2,3,4)$ are the output elasticities with respect each input and the production function is homogeneous of degree $\sum_{i=1} \beta_i$. The returns to scale is $\sum_{i=1} \beta_i$.

5. Empirical Results - Industry-specific Technical Efficiency Performance

The predicted technical efficiencies show substantial variability among industries ranging between 0.6683 and 0.9998 for the Cobb-Douglas frontier model with the mean technical efficiency of 0.8812 and standard deviation of 0.1371 for the data set 1991 - 1992. Variability in efficiencies of industries is also observed for the data set 1999 – 2000. Efficiencies for this set range between 0.8984 and 0.9979 with the mean efficiency of 0.9583 and standard deviation of 0.0338. The frequency distributions of the predicted technical efficiencies and the summary statistics for the efficiencies are presented in Table 10. It is evident from Table 10 that range of efficiency in 1991-1992 is larger than range of efficiency in 1999-2000. Mean efficiency of industrial establishments is also higher in 1999-2000. This implies that there is still a room for increasing industry revenue and welfare through efficiency improvement, and industry could reduce about 10 per cent of production costs if they could operate at full technical efficiency levels.

Table 10: Technical Efficiency Estimates of Industrial Establishments in Northwest Districts

Districts	Efficiency scores, 1991 - 1992	Efficiency scores, 1999 - 2000
Panchagarh	0.6683	0.9802
Thakurgaon	0.8387	0.9426
Dinajpur	0.9811	0.9979
Nilphamari	0.956	0.9522
Rangpur	0.9985	0.8984
Kurigram	0.9998	0.9766
Lalmonirhat	0.9243	0.9294
Gaibandha	0.6832	0.9888
Mean	0.8812	0.9583
Standard deviation	0.1371	0.0338
Minimum	0.6683	0.8984
Maximum	0.9998	0.9979
Northwest total	0.8675	0.9086
Bangladesh	0.9048	0.9879

The overall mean efficiency performance of industrial sector in Bangladesh is 0.8822 in 1991-1992 and 0.9563 in 1999-2000. These values are almost same with the overall mean efficiency values of industrial establishments in northwest Bangladesh. On an average in Bangladesh, the industrial sector has an opportunity of increasing production about 5 to 11 percent if they could operate at full technical efficiency levels without resort to technological progress, given the available factors of production. This suggests that policies should be taken to improvement of level of technological progress and quality of existing technological progress so that production of industrial sector could be increased significantly.

6. Conclusion

This paper aims to assess the performance of industrial establishments in northwest districts in Bangladesh with a comparison of that of industrial establishments in Bangladesh as a whole in terms of employment generation and value added by these establishments, assets and costs of them first and then by applying the stochastic frontier analysis. We also present an account of the number of industrial establishments in northwest districts- Dinajpur, Thakurgaon, Panchagarh, Nilphamari, Kurigram, Rangpur, Lalmonirhat and Gaibandha in the greater Rangpur-Dinajpur region of Bangladesh. We use data from Report on Bangladesh Census of Manufacturing Industries, 1991-1992 and 1999-2000.

Research shows that there are no remarkable numbers of large and medium industries except some small and cottage industries like, rice milling, bidi manufacturing industries, and wooden furniture manufacturing industries. It is implied from this analysis that there is scope of establishing industries in this region based on at least available surplus labour, agro-products as this region is an agro-based labour surplus region.

This study reveals that the performance of industrial establishments in this region in terms of number of persons engaged, employment generation and value added creation on an average is lower than that of the national level.

We investigate the level of efficiency performance of industries in northwest Bangladesh using the Cobb-Douglas stochastic frontier model. The model is estimated with the specification of the technical inefficiency effects model in a single stage estimation method applying the maximum likelihood estimation technique using data set for two periods. One set is for the period 1991 – 1992 and the other set is for the period 1999 – 2000. For both periods, we found an opportunity of industry production gain through improvement of efficiency of industries without resort to technological progress. Given the level of technical efficiency of industries, this research would humbly suggest introducing policies that would adopt new technological progress and improvement of existing level of technologies. This can provide technically optimal level of industrialization in northwest Bangladesh and hence improve the performance of industries, employment and income generation.

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