RESEARCH GRANT FINAL REPORT

An Extension of Data Envelopment Analysis with Double Bootstrap and Regional Stochastic Frontier Model

Anton Abdulbasah Kamil
Md. Azizul Baten
Hasmawati Hasan

School of Distance Education
Universiti Sains Malaysia

August 2011

UNIVERSITI SAINS MALAYSIA

UNIVERSITY RESEARCH GRANT FINAL REPORT
Geran Penyelidikan Universiti Laporan Akhir

A.	**TITLE OF RESEARCH:** I *Tajuk penyelidikan:* An Extension of Data Envelopment Analysis with Double Bootstrap and Regional Stochastic Frontier Model
B.	**PERSONAL PARTICULARS OF RESEARCHER** / *MAKLUMAT PENYELIDIK:*
(i)	**Name of Research Leader:** *Nama Ketua Penyelidik:* Assoc. Prof. Dr. Anton abdulbasah Kamil
	Name of Co-Researcher: *Nama Penyelidik Bersama:* Professor Dr. Md. Azizul Baten Pn. Hasmawati Hasan
(ii)	**School/Institute/Centre/Unit :** *Pusat Pengajian /Institut/Pusat/Unit :* School of Distance Education

C.	**Research Platform (Please tick (/) the appropriate box):** *Pelantar Penyelidikan (Sila tanda (/) kotak berkenaan):* [ ] A. **Life Sciences** *Sains Hayat* [✓] B. **Fundamental** *Fundamental* [ ] C. **Engineering & Technology** *Kejuruteraan & Teknologi* [ ] D. **Social Transformation** *Transformasi Sosial* [ ] E. **Information & Communications Technology (ICT)** *Teknologi Maklumat & Komunikasi* [ ] F. **Clinical Sciences** *Sains Klinikal* [ ] G. **Biomedical & Health Sciences** *Bioperubatan Sains Kesihatan*
D.	**Duration of this research :** *Tempoh masa penyelidikan ini :* ***Duration :** ....2 years and 3 months........................ *Tempoh :* **From** : ....01 July......... 2009__ **To** : ...30 September..........2011__ *Dari:* *Ke :*

E.	ABSTRACT OF RESEARCH

ABSTRACT OF RESEARCH

(An abstract of between 100 and 200 words must be prepared in **Bahasa Malaysia and in English**. This abstract will be included in the Annual Report of the Research and Innovation Section at a later date as a means of presenting the project findings of the researcher/s to the University and the community at large)

Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) both approaches are usually used for measuring efficiency of firms in productive systems and in the context of the multi-output, multi-input case, the statistical property for DEA estimators are necessary to establish by bootstrapping. The way stochastic frontier model has been developed and DEA extention was made in this study and corrected the bias generated by DEA approach using bootstrapping procedures. Translog stochastic frontier production function was found more preferable than Cobb-Douglas Stochastic frontier production function. The average technical efficiency of manufacturing firms was estimated 59%. The foreign financial institutions or firms were found less efficient in producing deposits. The overall deposits efficiency of all financial institution groups steadily increased over time. In addition, we developed an inventory-production model for a special class of generalized extreme value distribution. Inventory-demand ratio has been derived that evolves according to stochastic neoclassical differential equation.

Abstrak Penyelidikan

(Perlu disediakan di antara 100 - 200 perkataan di dalam **Bahasa Malaysia dan juga Bahasa Ingge** Abstrak ini akan dimuatkan dalam Laporan Tahunan Bahagian Penyelidikan & Inovasi sebagai satu ca untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti & masyarakat luar).

Analisis Penyampulan Data (DEA) dan Analisis Stokastik Sempadan (SFA) kedua-dua pendekatan biasanya digunakan untuk mengukur kecekapan syarikat dalam sistem produktif dan dalam konteks multi-output, kes multi-input, sifat-sifat statistik untuk estimator DEA diperlukan untuk ditetapkan oleh Bootstrap. Model sempadan secara stokastik telah dibangunkan dan perluasan DEA dibuat dalam kajian ini dengan mengoreksi bias yang dihasilkan dengan pendekatan DEA menggunakan prosedur Bootstrap. Translog fungsi pengeluaran stokastik sempadan dijumpai lebih disukai dari sempadan fungsi pengeluaran stokastik Cobb-Douglas. Kecekapan teknikal rata-rata syarikat perkilangan dijangka 59%. Institusi kewangan asing atau syarikat dijumpai kurang cekap dalam menghasilkan deposit. Kecekapan deposit keseluruhan dari semua kumpulan institusi kewangan terus meningkat dari masa ke masa. Selain itu, kami mengembangkan model persediaan-pengeluaran untuk kelas khusus pengedaran nilai umum ekstrim. Persediaan-permintaan nisbah telah diturunkan yang berkembang sesuai dengan persamaan pembezaan stokastik neoklasik.

F.	**SUMMARY OF RESEARCH FINDINGS** *Ringkasan dapatan Projek Penyelidikan*

This section was devoted to evaluate the overall performance of the productive / deposits / profit / wage efficiency estimates using a developed stochastic frontier model and an extended data envelopment analysis applied to panel data.

We analyzed the Translog Stochastic Frontier Production Function with distributional assumptions for the measurement of efficiency and the presence of one-sided error component was justified by the LR test individually, which was highly significant for (productive / deposits / profit / wage) Translog stochastic frontier model. We found that the technical inefficiency declined over the reference period and Translog production function was preferable to Cobb-Douglas production function.

In case of productive inefficiency effects model, we have found that the variable Herfindahl-Hirschman Index (HHI) shows negative but impact on firm production and temperature, significantly contributed to improve technical efficiency in production. We concluded that temperature was one of the major variables in order to improve technical efficiency in production, but it is surprising about rainfall which was found less efficient although, it is not statistically significant. For the Maximum Likelihood Estimation, γ is estimated at 0.99, this can be interpreted that 99% of random variation is the value added among the production due to inefficiency.

From the estimates of deposits stochastic frontier model we found that the coefficient of material input variable showed a negative sign, indicating that financial firms using less material (Stationary, postage, and other materials) were more productive. In deposits inefficiency effects model, the coefficient of total assets contains negative sign, indicating that the more the total asset the more the firm efficiency. The coefficients of financial firms (NBs and ISBs) demonstrate negative sign, implying that inefficiency level declines when competition increases. The estimated year wise average efficiency of the sample firms from the deposits model was 0.738 while group wise average technical efficiency is 0.777.

In case of wage augmented stochastic frontier model, the parameter estimates for employee is positive while that for operative turns to be negative. This implied that as the number of employee increases, output increases but as operative increases output decreases. These two estimates as a whole support the "shirking" variant of efficiency wage hypothesis. Because the supervisory intensity has same direction with number of employee but it is opposite direction with operative. The estimated coefficient of relative wage for operative appears to be positive, as it was expected, implying that the output increases with the increment of relative wage for operative. This estimate confirmed the prediction of efficiency wage hypothesis. But the coefficient of relative wage for employee turns to be negative which is surprising. The estimated results also showed that the Solow condition does not hold since the coefficients of the relative wage levels for employee and operative are significantly different than the coefficients of the employee and operative respectively. This implied that the estimated elasticity of effort with respect to wages is less than one.

On the other hand, for the Translog production function case, the variables capital, wage of operative relative, square terms of wage for employee relative and wage for operative relative, interaction in capital with wage for employee relative and wage for operative relative and interaction in between wage for employee relative and wage for operative relative are found to be significant affecting the productivity of firms.

The results indicated that the elasticities of the efficiency functions of both employee and operative are negative. This is on average -0.555 and -0.039 for employee and operative respectively. The results implied that efficiency of the worker is a decreasing function of relative wage with decreasing returns to scale. This fact, in turns, does not support the existence of efficiency wage hypothesis. The overall mean technical efficiency is estimated to be 0.398 for the manufacturing industry, which implies that only 39.8% of the potential outputs are being realized in manufacturing industry sector.

G.	**COMPREHENSIVE TECHNICAL REPORT** *Laporan Teknikal Lengkap* Applicants are required to prepare a comprehensive technical report explaining the project. (This report must be attached separately) Sila sediakan laporan teknikal lengkap yang menerangkan keseluruhan projek ini. [Laporan ini mesti dikepilkan] **List the key words that reflectour research:** *Senaraikan kata kunci yang mencerminkan penyelidikan anda:*

English	Bahasa Malaysia
Stochastic frontier analysis, Data envelopment analysis.	Analisis Stokastik Sempadan, Analisis Penyampulan Data
Deposite efficiency, Profit efficiency, Wage efficiency.	Deposit kecekapan, Kecekapan laba, Kecekapan upah.
Stochastic Cobb-Douglas and Translog production function, Likelihood ratio test, Inventory model, Stochastic differential equations.	Stokastik Cobb-Douglas dan Fungsi Pengeluaran Translog, Uji Nisbah Kebolehjadian, Model Inventori, Persamaan Pembezaan Stokastik.

H.

a) Results/Benefits of this research
Hasil Penyelidikan

No. *Bil:*	Category/Number: *Kategori/ Bilangan:*	Promised	Achieved
1.	**Research Publications (Specify target journals)** *Penerbitan Penyelidikan (Nyatakan sasaran jurnal)*		09 research articles and 06 conference proceedings
2.	**Human Capital Development**		
	a. Ph. D Students	Three (3) on going	
	b. Masters Students		
	c. Undergraduates (Final Year Project)		
	d. Research Officers		
	e. Research Assisstants		
	f. Other: Please specify		
3.	**Patents** *Paten*		
4.	**Specific / Potential Applications** *Spesifik/Potensi aplikasin*	It would integrate parametric, nonparametric and semi-parametric methods with application to firms	It integrated parametric and nonparametric methods with application to financial institutions, manufacturing firms
5.	**Networking & Linkages** *Jaringan & Jalinan*	Research Collaborations with Department of Statistics School of Physical Sciences Shahjalal University of Science and Technology Sylhet-3114, Bangladesh	
6.	**Possible External Research Grants to be Acquired** *Jangkaan Geran Penyelidikan Luar Diperoleh*		

- Kindly provide copies/evidence for Category 1 to 6.

b) **Equipment used for this research.**
Peralatan yang telah digunakan dalam penyelidikan ini.

Items *Perkara*	Approved Equipment	Approved Requested Equipment	Location
Specialized Equipment Peralatan khusus			
Facility Kemudahan			
Infrastructure Infrastruktur			

- Please attach appendix if necessary.

I. BUDGET / ***BAJET***

Perbelanjaan :Expenditure

Project Account No. : 1001 / PJJAUH/ 817130

Total Approved Budget : RM 95,200.00
Total Additional Budget : RM
Grand Total of Approved Budget : RM 95,200.00

Yearly Budget Distributed

Year 1 : RM 55,300.00
Year 2 : RM 39,900.00
Year 3 : RM

Additional Budget Approved

Year 1 : RM
Year 2 : RM
Year 3 : RM

Total Expenditure : RM 95,200.00
Balance : RM 0

- **Please attach final account statement from Treasury**

Signature of Researcher
Tandatangan Penyelidik

3. 8. 2011
Date
Tarikh

Purchase Requisition ▸ Purchase Order ▸ Suppliers ▸ Maintenance ▸ Financials ▸ Coda Info ▸ Reports ▸ Admin ▸

UserCode: ASMAHANI / USMPGLIVE / PJJAUH **Program Code: Votebook9100** **Current Program : Votebook (Header)**

Current Date : 03/08/2011 12:05:07 PM **Version: 13.92, Last Updated at 30/05/2011** **DB: 13.02, 09/27/2010 VB: 13.01, 03/14/2011** **Switch Language : English /Malay**

Wildcard : eg. Like 100%, Like 10%1, Like %1

Element 1: 1001 Element 2: % Element 4: PJJAUH

Element 5: 811130 Year: 2011

Detail	Excel	Budget Rule	Budget Control	Account Description	Budget Account Code	Roll over	Budget	Cash Received	Advanced	Commit	Actual	Available	Percentage
Detail	Excel	489	T	Projek Kumpulan Wang Uni Penyelidikan	1001.111.0.PJJAUH.811130	51,461.29	0.00	0.00	0.00	0.00	15,700.00	35,761.29	0.00%
		489	T	SubTotal		51,461.29	0.00	0.00	0.00	0.00	15,700.00	35,761.29	0.00%
Detail	Excel	490	T	Projek Kumpulan Wang Uni Penyelidikan	1001.221.0.PJJAUH.811130	-19,730.35	0.00	0.00	0.00	0.00	360.40	-20,090.75	0.00%
Detail	Excel	490	T	Projek Kumpulan Wang Uni Penyelidikan	1001.223.0.PJJAUH.811130	775.74	0.00	0.00	0.00	0.00	0.00	775.74	0.00%
Detail	Excel	490	T	Projek Kumpulan Wang Uni Penyelidikan	1001.227.0.PJJAUH.811130	14,169.00	0.00	0.00	0.00	0.00	1,314.11	12,854.89	0.00%
Detail	Excel	490	T	Projek Kumpulan Wang Uni Penyelidikan	1001.229.0.PJJAUH.811130	-2,375.17	0.00	0.00	0.00	0.00	12,652.00	-15,027.17	0.00%
		490	T	SubTotal		-7,160.78	0.00	0.00	0.00	0.00	14,326.51	-21,487.29	0.00%
Detail	Excel	491	T	Projek Kumpulan Wang Uni Penyelidikan	1001.335.0.PJJAUH.811130	-14,274.00	0.00	0.00	0.00	0.00	0.00	-14,274.00	0.00%
		491	T	SubTotal		-14,274.00	0.00	0.00	0.00	0.00	0.00	-14,274.00	0.00%
		9999		GrandTotal		30,026.51	0.00	0.00	0.00	0.00	30,026.51	0.00	0.00%

H.	**COMMENTS OF PTJ'S RESEARCH COMMITTEE** *KOMEN JAWATANKUASA PENYELIDIKAN PERINGKAT PTJ*
	General Comments: *Ulasan Umum:* This project published 9 journal articles, 6 proceeding papers and has engaged 3 PhD students. **Signature and Stamp of Chairperson of PTJ's Evaluation Committee** *Tandatangan dan Cop Pengerusi Jawatankuasa Penilaian PTJ* PROF. MADYA DR. MUSTAFA FADZIL FARID WAJIDI *Timbalan Dekan* (Pengajian Siswazah Dan Penyelidikan) Pusat Pengajian Pendidikan Jarak Jauh Universiti Sains Malaysia **Date** : 3/8/11. *Tarikh* : **Signature and Stamp of Dean/ Director of PTJ** *Tandatangan dan Cop Dekan/ Pengarah PTJ* PROF. MADYA DR. HABIBAH HJ. LATEH *Dekan* Pusat Pengajian Pendidikan Jarak Jauh Universiti Sains Malaysia **Date** : *Tarikh* :

RESEARCH GRANT TECHNICAL REPORT

An Extension of Data Envelopment Analysis with Double Bootstrap and Regional Stochastic Frontier Model

Anton Abdulbasah Kamil
Md. Azizul Baten
Hasmawati Hasan

School of Distance Education
Universiti Sains Malaysia

August 2011

An Extension of Data Envelopment Analysis with Double Bootstrap and Regional Stochastic Frontier Model

Project Leader: Assoc. Prof. Dr. Anton abdulbasah Kamil
Co-Researchers: Professor Dr. Md. Azizul Baten
Pn. Hasmawati Hassan
School of Distance Education, USM, Penang, Malaysia.
RU Field: Fundamental

Abstract

During the last years, great attention has been given to the assessment and improvement of the performance of productive systems. Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) both approaches are usually used for measuring efficiency of firms in productive systems. In the context of the multi-output, multi-input case, the statistical property for DEA estimators are necessary to establish with bootstrapping. The way stochastic frontier model has been developed and DEA extention was made in this study and corrected the bias generated by DEA approach using bootstrapping procedures. Translog stochastic frontier production function was found more preferable than Cobb-Douglas Stochastic frontier production function. The average technical efficiency of manufacturing firms was estimated 59%. The foreign financial institutions or firms were found less efficient in producing deposits. The overall deposits / profit / wage efficiency was examined for all financial institution or firms over time. In addition, we developed an inventory-production model for a special class of generalized extreme value distribution. Inventory-demand ratio was derived that evolves according to stochastic neoclassical differential equation.

Introduction

In recent years the performance measurement concerns for financial institutions have attracted a great deal of attention. The structures of financial service industries are changing rapidly, it is of considerable interest to measure the efficiency of evolving institutions. Efficiency measure is an essential topic for researchers about industry's performance. In this context, there are two types of modeling: a non parametric one, represented by Data Envelopment Analysis (DEA) and a parametric one, represented by Stochastic Frontier Analysis (SFA). Both DEA and SFA approaches are used for measuring efficiency introduced initially by Farrell (1957). The way Seitz (1970) used linear programming techniques to calculate measures of Farrel-type efficiencies for the single-output case. However, until now Charnes, Cooper and Rhodes (1978) has the generalized linear programming method, known as DEA, been applied widely to estimate technical efficiency, at first within the operating research and management science and later, within the economics community. In the context of the multi-output, multi-input case, the only currently feasible method to establish the statistical property for Data Envelopment Analysis (DEA) estimators is done by bootstrapping (Simar and Wilson 1998, 2000). Only a few recent analyses have been applied the smoothed homogeneous bootstrap in order to determine the variability of DEA efficiency estimates (Brummer 2001; Balcombe et al., 2005). In addition, the problem of serial correlation among estimated efficiencies highlighted in Simar and Wilson (2007) has not been tackled in any of these studies.

In this study we would like to develop the parametric Stochastic Frontier Analysis (SFA) and an extension of nonparametric DEA estimation approaches to address this issue. This study is the first study estimating productive efficiencies to use bootstrapping procedures to correct the bias generated by DEA approach. It is the first to use a weighted Tobit procedure to correct for that same bias. Tobit analysis would be used to asses the factors influencing efficiency in the final stage.

Methodology

I. Data Envelopment Analysis and Regional Stochastic Frontier Model

In this study two methods: parametric stochastic frontier analysis method and non-parametric Data Envelopment Analysis method will adopt for investigating economic and cost efficiency and its determinants of firms. Due to difficulties to choose one over the other, this study will apply to both and compares their results with the idea that findings are reliable. Following Chavas et al. (2005), and others, we will apply nonparametric Data Envelopment Analysis (DEA) method to estimate output-based technical, allocative, and scale efficiencies. Based on the smoothed bootstrap procedure for Data Envelopment Analysis estimators proposed by Simar and Wilson (2000), this study will estimate the bias and the confidence interval of DEA estimators for efficiency. We then will use the estimated efficiencies to identify factors explaining differences among firms by standard and weighted Tobit analysis. The computer software like FRONTIER 4.1 and DEAP 2.1 will be used in this study developed by Coelli, T.J. (1996a, 1996b).

II. Bootstrapping Technique with Data Envelopment Analysis

While Data Envelopment Analysis methods have been widely applied, most researchers largely ignored the statistical properties in the estimators. Simar and Wilson (2007) noted that the DEA efficiency estimates are biased and serially correlated, which invalidates conventional inference in two-stage approaches. The rationale behind bootstrapping is to simulate a true sampling distribution by mimicking the data generating process. The bootstrap procedure what we would like to apply in this study followed by Simar and Wilson's (2007). This study will serve the smoothed bootstrapping procedure using FEAR 1.0: A Software Package for Frontier Efficiency Analysis developed by Wilson (2005) in the R Platform.

III. Tobit Analysis

Tobit analysis, we will use in the final stage after calculating the efficiency scores to assess the factors influencing efficiency. In addition, the interest is to develop the procedures for estimating the bias in DEA estimators for scale and allocative efficiency in this study, if not so, the conventional Tobit analysis would apply to estimate the efficiencies.

Achievment

Name of articles/Manuscripts/Books published

1. Baten, M.A., & Kamil, A.A., A stochastic frontier model on measuring online bank profit efficiency, *South African Journal of Business Management.* 42 (4) December 2011 (Accepted, forthcoming).

2. Md. Azizul Baten and Anton Abdulbasah Kamil, 2011, Optimal Control of Inventory-Production Systems with Gumbel Distributed Deterioration, *International Journal of Physical Sciences* 6(7), pp. 1851-1862.

3. Md. Azizul Baten, Anton Abdulbasah Kamil and Mohammad Anamul Haque, 2010, Productive Efficiency of Tea Industry: A Stochastic Frontier Approach, *African Journal of Biotechnology* Vol. 9 (25), pp. 3808-3816.

4. Md. Azizul Baten and Anton Abdulbasah Kamil, 2010, A Stochastic Frontier Model on Measuring Online Bank Deposits Efficiency, *African Journal of Business Management* 4(12), pp. 2438-2449.

5. Rana, M.M., Baten, M.A., & Kamil, A.A., 2010, A Stochastic Frontier Approach for Empirical Tests of Efficiency Wage Models, *Scientific Research and Essays* Vol. 5(11), pp. 1234-1242.

6. A. H. M. Saidul Hasan, Md. Azizul Baten, Anton Abdulbasah Kamil and Sanjida Parveen, 2010, Adoption of E-Banking in Bangladesh: An Exploratory Study, *African Journal of Business Management (AJBM)* 4(13), pp. 2718-2727.

7. Md. Azizul Baten and Anton Abdulbasah Kamil, 2010, Direct Solution of Riccati Equation Arising in Inventory Production Control in a Stochastic Manufacturing System, *International Journal of Physical Sciences (IJPS)* Vol. 5(7), pp. 931-934.

8. Md. Zobaer Hasan, Anton Abdulbasah Kamil and Md. Azizul Baten, Measuring Dhaka Stock Exchange Market Efficiency: A Stochastic Frontier Analysis, *African Journal of Business Management,* (Accepted forthcoming), 2011.

9. Kanis Fatama Ferdushi, Md. Azizul Baten , Anton Abdulbasah Kamil and Adli Mustafa, Wage AugmentedStochastic Frontier Model with Truncated Normal Distribution, *International Journal of Physical Sciences,* (Accepted forthcoming), 2011.

Title of Paper Presentations (International/Local)

1. Baten, M.A., & Kamil, A.A., 2009, An Optimal Control Approach to Inventory-Production Systems with Weibull Distributed Deterioration, *The 16th Mathematical Conference of Bangladesh Mathematical Society*, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, 17-19 December, 2009.

2. Baten, M.A., & Kamil, A.A., 2009, Inventory Management Systems with Hazardous Items of Two-Parameter Exponential Distribution, *The 2nd International Conference of Global Business and Management Forum, USA*, University of Dhaka, Dhaka, Bangladesh, 22-23 December, 2009.

3. Baten, A.A., & Kamil, A.A., 2010, Production Inventory Planning in a Stochastic Manufacturing System with Discounted Cost, *Joint Mathematics Meetings*, San Francisco, California, USA, January 10-16, 2010.

4. Baten, M.A., & Kamil, A.A., 2010, Riccati Solutions of Production Control in a Stochastic Manufacturing System with Degenerate Demand, *The First International Conference on Mathematics and Statistics- AUS-ICMS'10*, American University of Sharjah, United Arab Emirate, March 18-21, 2010.

5. Baten, M.A., & Kamil, A.A., 2010, Optimal Fuzzy Control with Application to Discounted Cost Production Inventory Planning Problem, *The 2010 International Conference of Applied and Engineering Mathematics*, Imperial College, London, UK, June 30 – July 2, 2010.

6. Baten, M.A., & Kamil, A.A., 2010, Measuring online Bank profit efficiency: A stochastic frontier analysis, *Proceeding of the 6th International Conference on Mathematics, Statistics and Applications (ICMSA2010)*, Kuala Lumpur, November 3-4, pp. 336-350, 2010.

Human Capital Development

1. Three (03) PhD student on going.

References

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Seitz, W.D. (1970). "The Measurement of Efficiency Relative to a Frontier Production Function". *American Journal of Agricultural Economics,* 52, 505–511.

Simar, L., and P., Wilson. (1998). "Sensitivity Analysis of Efficiency Scores: How to Bootstrap in Nonparametric Frontier Models." *Management Science* 44(1), 49-61.

Simar, L., and P., Wilson. (2000). "A General Methodology for Bootstrapping in Non-Parametric Frontier Models." *Journal of Applied Statistics* 27(6), 779-802.

Simar L, and Wilson P. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. Journal of Economics, 136(1), 31–64.

Wilson, P.W. (2005). *FEAR 1.0User's Guide*. Department of Economics, Clemson University, Clemson, South Carolina. Accessed on April 4, 2006, at http://www.clemson.edu/economics/faculty/wilson/Software/FEAR/FEAR-0.913/fear-0.913_user_guide.pdf

ARTICLES PUBLISHED

anton abdulbasah kamil

From: Md baten [baten_math@yahoo.com]
Sent: Thursday, May 26, 2011 5:10 PM
To: Anton Abdulbasah Kamil
Subject: Fw: ARTICLE: 10/52 : in SAJBM

Please see the forwarded meassage from the editor of South Africal Journal of Bussiness and Management (SAJBM).
The title of the article:
Md. Azizul Baten and Anton Abdulbasah Kamil, A Stochastic Frontier Model on Measuring Online Bank Profit Efficiency

----- Forwarded Message ----
From: Leurs Marion USB <Marion.Leurs@usb.ac.za>
To: Md baten <baten_math@yahoo.com>
Sent: Thu, May 26, 2011 2:06:00 AM
Subject: RE: ARTICLE: 10/52 : in SAJBM

Dear Dr Baten
Your article will be published in SAJBM 42(4) December 2011.
Best wishes
Marion

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From: Md baten [mailto:baten_math@yahoo.com]
Sent: 26 May 2011 04:46 AM
To: Leurs Marion USB
Cc: anton abdulbasah kamil

A Stochastic Frontier Model on Measuring Online Bank Profit Efficiency

Md. Azizul Baten and Anton Abdulbasah Kamil

Mathematics Section, School of Distance Education, Universiti Sains Malaysia

11800 USM, Penang, Malaysia

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Abstract

This study proposed that Battese and Coelli (1995) inefficiency model be applied as a unified and consistent framework in exploring the determinants of important factors causing profit efficiency differential on banking industry in Bangladesh. Using stochastic frontier technique we estimated bank specific profit efficiency for the period 2000 to 2007. This study attempted to examine the changes in the profit efficiency in accordance with NBs (Nationalized Commercial Banks), ISBs (Islamic Banks), FBs (Foreign Banks) and PBs (Private Banks) and significant variations of efficiencies across different kinds of banks in time periods. We found that the profit inefficiency has declined over the reference period and Translog Production Function is more preferable than Cobb-Douglas Production Function. Our results showed that Nationalized Commercial Banks were significantly inefficient and on the contrary ISBs, FBs, and PBs were efficient in producing profit and noteworthy. The estimated year wise average efficiencies of the sample banks from the profit efficiency model was 0.664 while group wise average profit efficiency was 0.639. Dhaka Bank is highly efficient with score 0.89 and AB Bank was found lowest efficient with score 0.35 according to the sample data.

Key Words: Profit efficiency, Stochastic Frontier Analysis, Banking Industry.

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INTRODUCTION

In recent years the performance measurement concerns for financial institutions have attracted a great deal of attention. The structures of financial service industries are changing rapidly, it is of considerable interest to measure the efficiency of evolving institutions. Efficiency measure is an essential topic for researchers about industry's performance. Creditors and investors use such efficiency evaluations to judge past performance and current position of banks. Bank efficiency is a socially optimal target since it reduces the average cost of financial transactions and therefore enhances the society's welfare. Due to the growth of competition, bank management is interested in enhancing efficiency. Bank efficiency studies are of crucial importance for operational and academic proposes (Berger *et al.*, 1997).

Many studies evaluated a wide range aspect of banks efficiency in different economies. Profit efficiency indicates how well a bank is predicted to perform in terms of profit relative to other banks in the same period for producing the same set of outputs. Despite the wide agreement on the relevance of profit efficiency analysis, the technical difficulties with the measurement and decomposition of profit inefficiency were the main reasons for the small number of empirical studies on banking profit efficiency. Both parametric and non-parametric techniques have been employed to compute efficiency scores, providing valuable insights not only for the academic research but also for regulation and management decisions (Berger and Humphrey, 1997). Nevertheless, the majority of these studies limit their efficiency analysis to the cost side (*e. g.* Berger, Hunter and Time, 1993; Resti, 1997), recent studies have given more attention to profit efficiency. Indeed, among the 130 studies surveyed by Berger and Humphrey (1997), only fourteen of those studies employ a profit efficiency perspective. Some studies (e.g., Guevara and Maudos, 2002) provide banking profit efficiency scores for several European countries, including Portugal. So far, there is quite fair number of researches that studied banking efficiency in less developed countries. For example: Saudi (Al-Faraj *et al.*, 1993), Bangladesh (Sarker, 1999), Kuwait (Limam, 2002), Turkey (Isik and Hassan, 2002a and b), Jordan (Isik *et al.*, 2003), Bahrain (Hassan *et al.*, 2003), Malaysia (Sufian and Ibrahim, 2005), Pakistan (Limi, 2004), and U.A.E. (Rao, 2005).

Studies that applied the profit efficiency found some evidence of improved profit efficiency. (see Berger and Humphrey 1992b; Berger, Hancock, and Humphrey 1993; Berg, et al. 1993; Kaparakis et. al., 1994; Kwan and Eisenbeis, 1996; Allen and Rai 1996; Berger and Mester, 1997; Bikker, 2001. The majority of studies investigating banking profit efficiency adopt a parametric approach following the prominent works of Berger and Mester (1997), DeYoung and Nolle (1996) and DeYoung and Hasan (1998). The few available studies that estimate profit frontier functions report efficiency levels that are much lower than cost efficiency levels, implying that the most important inefficiencies are on the revenue side (Maudos et al., 2002). Maudos and Pastor (2003) is the only study where alternative profit efficiency scores are computed with a non-parametric approach. Joana Resende and Elvira Silva (2007) identified the sources of profit inefficiency using Data Envelopment Analysis (DEA). A few studies have looked into Bangladesh banking sector (Raihan 1998, Choudhury et al., 1999, Hasan et al., 1999, Choudhury 2000, Choudhury 2002, Rahman (2003); Hasan and Baten 2005, Nadim et al., 2007). To our knowledge, there is no study have focused exclusively on the profit efficiency of Bangladesh banking sector using Stochastic frontier analysis. Therefore this study intends to reveal the overall performance of commercial banks with loan default and measuring bank efficiency in Bangladesh in the context to both productivity and profitability.

The Data Envelopment Analysis in measuring technical efficiency does not impose any assumptions about production functional form and does not take into account random error hence the efficiency estimates may be bias if the production process is largely characterized by stochastic elements. Decisive virtues of Stochastic Frontier Analysis are that it covers both the random noises, e.g., due to well-known measurement problems, and systematic differences between banks in the sample due to heterogeneity across banks (Kumbhakar and Lovell 2000). The present paper utilizes this Battesse and Coelli (1995) model, which is assumed to behave in a manner consistent with the stochastic frontier concept and it is used to examine the profit efficiency level of banks in Bangladesh. The main focus of our study is to measure the bank profit efficiency in accordance with NBs (Nationalized Commercial Banks), ISs (Islamic Banks), FBs (Foreign Banks) and PBs (Private Banks) in Bangladesh. To determine the important factors causing profit efficiency differential on banking industry in Bangladesh is also of our interest.

Background of Bangladesh Banking Industry and Its Importance

The banking industries are the place where we often wind up when we are seeking a loan to purchase a new automobile, tuition for college or a professional school, financial advice on how to invest our savings, credit to begin a new business, a safe deposit box to protect our most valuable documents, a checking account to pay for purchases of goods and services, or a credit or debit card so we can conveniently keep track of when and where we spend our money, financial firms other than banks are selling us these same services, but banks still head the list of financial service providers in many markets. The banking system of Bangladesh consists of four nationalized commercial Banks, around forty private commercial banks, nine foreign multinational banks and some specialized banks. Grameen Bank is a specialized micro-finance institution, which revolutionized the concept of micro-credit and contributed greatly towards poverty reduction and the empowerment of women in Bangladesh. Banks are the main vehicles for mobilizing invisible funds and channeling those funds to faster the growth of the productive sectors of the economy. Question arises how successfully the nationalized private commercial banks are serving the country, how far they have achieved their desired goals? The nationalized commercial banks are overcome with the vicious problem of corruption, inefficiency, loan default etc. although the private commercial banks are efficient in their commercial activities and solving the problem of loan default. The Bangladesh banking sector relative to the size of its economy is comparatively larger than many economies of similar level of development and per capita income. Private Banks are the highest growth sector due to the dismal performances of national/government banks. Foreign Banks are also the growth sector due to the performances of national commercial banks. They tend to offer services providing disbursed loan and defaulted loan as well as are playing a pioneer role in introducing modern financial products and services. Out of the specialized banks, two (Bangladesh Krishi Bank and Rajshahi Krishi Unnayan Bank) were created to meet the credit needs of the agricultural sector while the other two

(Bangladesh Shilpa Bank (BSB) and Bangladesh Shilpa Rin Sangtha (BSRS)) are for extending term loans to the industrial sector. The total size of the banking sector at 26.54% of GDP dominates the financial system, which is proportionately large for a country with a per capita income of only about US$540. The non-bank financial sector, including capital market institutions is only 3.22% of GDP, which is much smaller than the banking sector. Access to banking services for the population has improved during the last three decades. While population per branch was 57,700 in 1972, it was 19,800 in 1991. In 2001 it again rose to 21,300, due to winding up of a number of branches and growth in population. Compared to India's 15,000 persons per branch in 2000, this indicates that the banking system in Bangladesh is a significant problem.

Insert Table 1 here

METHODOLOGY

Measurement of Variables

One of the crucial debated issues in the banking literature is output measurement. Under production approach output is measured by the number and type of transactions or accounts and inputs used are only physical units such as labor and capital, since, only physical inputs are needed to provide financial services. Under intermediation approach, financial institutions are thought of as primarily intermediating funds between savers and investors. Under this approach, the inputs of the bank are essentially financial capital, and outputs are measured by the volume of loans and investments outstanding. The present study adopts production approach to specify outputs and inputs of commercial banks. Accordingly, profits are defined as the outputs of commercial banks which are produced by using inputs like labor, capital and materials. All nominal values are converted to real by deflating with GDP deflator and all values are in their natural logarithms.

Data Set

We have used data for the period of 2001-2007 from 20 commercial banks of Bangladesh. Banks are grouped into four categories (i) National Banks (NBs), (ii) Islamic Banks (ISBs), (iii) Foreign Banks (FBs), (iv) Private Banks (PBs). Most of the data are collected from the annual reports of the specific banks of Bangladesh and rest of them are collected from annual accounts of Scheduled Commercial Banks published by Bangladesh Bank, the central bank of Bangladesh. Deposits are measured as total deposits. Capital is measured as fixed assets (which includes premises, furniture and other fixed assets). Number of employees is measured as the total number of employees. Material is measured as the sum of expenditure on printing and stationeries, postage, telegrams and telephone etc. All nominal values are converted on real by deflating with GDP deflator and all values are in their natural logarithms.

Dependent Variable

Profit (Y): Banks and other financial institutions are simply businesses organized to maximize the profitability and that is why the performance of a commercial bank is measured by its profit efficiency. For this reason we have used profit as one of the most important outputs of a bank. In this study profit is equal to the pre-tax profit for all commercial banks. The nominal profit (output) values are deflated by respective consumer price index.

Independent Variables

Capital (X_1): Capital is the input variable representing the fixed assets of a bank in a year which also adds premises, furniture and fixture. Capital figures are deflated by capital price index.

Material (X_2): For the banking sector, material has been used as the sum of expenditure on printing and stationeries and postage, telegrams and telephones etc. Material prices are deflated by non-food price index.

Labor (X_3): Labor is one of the most important inputs to measure the productivity of a firm. Here labor means number of employee and is measured as the total number of employees which include officers, sub-ordinates and clerks.

Time (X_4): To find the productive efficiency of a bank over time we have used time as the input variable. In this study we have collected data of seven years from 2001 to 2007 and used 1 for year 2001, 2 for 2002 and so on.

Explanatory Variables

Time (Z_1): Time is also used in this study as influencing variable.

Total Asset (Z_2): Total asset used as the influencing variable and is the sum of all assets and their book value.

Herfindahl-Hirschman Index (HHI) (Z_3): The Herfindahl-Hirschman index takes into accounts both the relative size and number of banks in the banking sector. Mathematically, HHI is described as follow: $HHI = \sum_{i=1}^{N} S_i^2$ where N is the number of banks and S_i is share of the i^{th} bank. HHI is known as measure of competition which is measured as the sum of squared of the output share of each bank in the output of considered total banks in Bangladesh.

NB, ISB, FB, and **PB** are bank group specific dummies for National Bank, Islamic Bank, Foreign Bank, and Private Bank respectively. The dummy variables can take either 1 or 0 depending on data availability or not respectively.

A Theoretical Stochastic Frontier Model

Technical efficiency measurement by frontier method is based on the assumption that a gap normally exists between a firm's actual and potential levels of technical performance. Thus the technical efficiency is measured as the ratio between actual output and the potential output. While there are various methods of measuring technical efficiency (see Lovell 1993, Coelli et al., 1998, and Kumbhakar and Lovell 2000), in the present study we use the approach proposed by Battese and Coelli (1995) which explicitly account for statistical noise. The specification of the model may be expressed as:

$$Y_{it} = \beta X_{it} + (V_{it} - U_{it}) \quad i = 1,2,\ldots\ldots,N; \quad t = 1,2,\ldots\ldots,T \quad \ldots\ldots\ldots(1)$$

where Y_{it} is the (logarithm of) output of the i^{th} bank in t^{th} period; X_{it} is a vector of input quantities; β_i's are unknown parameters to be estimated; V_{it}'s random variables which are assumed to be i.i.d.,

$N(0, \sigma_v^2)$ and independent of U_{it} ; U_{it}'s are non-negative random variables which are assumed to account for technical inefficiency in output and to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution; where $U_{it} = Z_{it}\delta$; where; Z_{it} is a $(1 \times p)$ vector of variables which may influence the inefficiency of bank industry and δ is a $(p \times 1)$ vector of parameters to be estimated. The parameterization from Battese and Corra (1977) are used replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$.

The Technical inefficiency effect U_{it} in the stochastic frontier model is specified as follows;

$$U_{it} = Z_{it}\delta + W_{it} \quad ....(2),$$

where, the random variable, W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_{it}\delta$. Parameters of the stochastic frontier given by equation (1) and inefficiency model given by equation (2) are simultaneously estimated by using maximum likelihood estimation (Battese and Coelli 1993). After obtaining the estimates of U_{it} the technical efficiency of the i-th bank industry at t-th time period is given by:

$$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) \quad ....(3).$$

A Stochastic Frontier Model of Profit Inefficiency

The functional form of the profit Translog stochastic frontier production model is defined as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 X_4 + \tfrac{1}{2}\left(\beta_{11} \ln X_{1it}^2 + \beta_{22} \ln X_{2it}^2 + \beta_{33} \ln X_{3it}^2 + \beta_{44} X_4^2\right)$$
$$+\beta_{12} \ln X_{1it} * \ln X_{2it} + \beta_{13} \ln X_{1it} * \ln X_{3it} + \beta_{14} \ln X_{1it} * X_4 + \beta_{23} \ln X_{2it} * \ln X_{3it} + \beta_{24} \ln X_{2it} * X_4$$
$$+\beta_{34} \ln X_{3it} * X_4 + V_{it} - U_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5),$$

where, the subscripts i and t represent the i-th bank industry and the t-th year of observation, respectively; $i = 1, 2, \ldots, 20$; $t = 1, 2, \ldots, 7$;

Y_{it} denotes the output variables (profit) of the ith bank industry in the t-th period in values (taka);

X_{1it} denotes capital (fixed assets of a bank in a year which also adds premises, furniture and fixture) of i-th bank industry in the t-th period;

X_{2it} represents materials (the sum of expenditure on printing and stationeries and postage, telegrams and telephones etc) of i-th bank industry in the t-th period;

X_{3it} represents labor (the total number of employees which include officers, sub-ordinates and clerks) of i-th bank industry in the t-th period;

X_4 represents year of observation;

"ln" refers to the natural logarithm.

Further, the bank industry specific inefficiency is considered as a function of some explanatory variables and the inefficiency effects model is defined as:

$$U_{it} = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 NB + \delta_5 ISB + \delta_6 FB + \delta_7 PB + W_{it} \quad ....(6),$$

where δ_0 is the intercept term and δ_j $(j = 1, 2, 3, 4, 5, 6, 7)$ is the parameter for the j-th explanatory variable, Z_1=Year of observation, Z_2=Total Assets, Z_3= Herfindahl-Hirschman Index, NB is the dummy variable for Nationalized Commercial Banks: NB=1 if an observation involves a Nationalized Commercial Bank, zero otherwise; ISB is the dummy variable for Islamic banks: ISB=1 if an observation involves an Islamic bank, zero otherwise; FB is dummy variable for Foreign Banks: FB=1 if an observation involves a Foreign Bank, zero otherwise; PB is dummy variable for Private Banks: PB=1 if an observation involves a Private Bank, zero otherwise;

Likelihood Ratio Tests and Hypothesis

The following hypotheses requires testing with the generalized likelihood ratio test statistic is defined by $\lambda = -2\ln[L(H_0)/L(H_1)] = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}$ ....(7) where $L(H_0)$ and $L(H_1)$ are the value of the likelihood function for the profit frontier model under the null and alternative hypothesis. Under the null hypothesis, this test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Taymaz and Saatci 1997). These are obtained by using the values of the log–likelihood functions for the banking industries and the stochastic frontier production function.

The following null hypotheses will be tested:

$H_0 : \beta_{ij} = 0$, the null hypothesis that identifies an appropriate functional form either the restrictive Cobb-Douglas or Translog production function. It specifies that the second-order coefficients of the stochastic frontier production function are simultaneously zero.

$H_0 : \gamma = 0$, the null hypothesis specifies that the technical inefficiency effects in banks are zero. This is rejected in favor of the presence of inefficiency effects. Here γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiency and defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier models by using the computer program frontier version 4.1 developed by Coelli (1996). If the null hypothesis is accepted this would indicate that σ_u^2 is zero and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square (OLS).

Further $H_0 : \eta = 0$, the null hypothesis that the technical inefficiency effects are time invariant i.e., there is no change in the technical inefficiency effects over time. If the null hypothesis is true, the generalized likelihood ratio statistic λ is asymptotically distributed as a chi-square (or mixed chi-square) random variable.

RESULTS AND DISCUSSION

In this section Ordinary Least Square Estimates (OLS) and Maximum Likelihood Estimates (MLE) of the parameters reported in the context of bank specific profit efficiency of Bangladesh followed by Translog stochastic frontier model. The ordinary least square estimates of parameters were obtained by grid search in the first step and then these estimates were used to estimate the maximum likelihood estimates of the parameters treated as the profit frontier estimates of Translog stochastic frontier production model.

The ordinary least squared estimates of profit efficiency model were presented in the table 2. First order coefficients of the parameters of profit efficiency model were statistically significant in case of OLS estimation at different level of significance but some second order variables were found statistically insignificant. In OLS estimates all first order parameters in profit efficiency model showed positive sign. All input variables except some second order variables were indispensable contributors to boost the bank profit efficiency in Bangladesh.

Insert Table 2 here

The maximum likelihood estimates (MLE) of parameters in the profit efficiency model along with inefficiency estimates reported in the table 3 and 4. The maximum likelihood estimates of the coefficients of capital and material were found to be significant with the values -0.696 and 0.887 respectively while the coefficients of labor and time found insignificant with 0.062 and 0.053 respectively. The insignificance of the estimated labor coefficients was not surprising given that most banks may be still overstaffed even after many years of reforms. The most expected result observed in inefficiency effects model of profit efficiency and the result for the estimated coefficient of time with -0.370 indicated that day by day the level of efficiency is being increased. It was observed that time, total assets, Herfindahl-Hirschman Index were having negatively significant in this model.

Insert Table 3 here

In the inefficiency effects model, a positive coefficient value increased the level of inefficiency and vice-versa. Hence from the result it was reported that time, total assets and Herfindahl-Hirschman Index were found decreasing the level of inefficiency. Other explanatory variables in the inefficiency model were the dummies of four banks group taking value 0 or 1. From the coefficients of these variables it was clear that Foreign Banks and Private Banks were more efficient in profits making than that of their counterparts Nationalized Commercial Banks and Islamic Banks. The negative coefficient of time indicated that the profit level tended to increase by 1.37 percent per year over the time period.

Insert Table 4 here

The estimated results of the profit efficiency model were reported in the figures 1, 2 and 3 according to group wise, year wise and bank wise respectively. It was observed that on an average, Bangladeshi banks were 66.4 percent efficient in profits making services relative to the best performing bank during the study period. In case of profit efficiency, foreign banks were most efficient (68.8 percent) along with private banks (68.7 percent). These findings are in line with the argument that foreign banks are superior as they normally have advanced technology and skills; sophisticated services and broader international networks (Levine, 1996; Unite and Sullivan, 2003). National banks and Private banks were relatively less efficient than foreign banks, these results contradicted with the finding of (Iza et al. 2009) but supported with the result of (Tahir et al. 2010). From this study it was revealed that Government owned banks were least efficient that increase profits level with 58.4 percent. However, the implication of the result of (Raulin, 2008) is that foreign banks are not always more efficient than domestic banks in developing countries, and even in a country with low income level. During the period 2001 to 2004, profit efficiency of nationalized commercial banks were almost stable and it was around 45.8 percent but in the following year efficiency scores increased dramatically and it became almost doubled with 87.5 percent. The findings of this study suggest that foreign banks are more profit efficient than domestic banks and it was supported by (Kiyota, 2009). Again the efficiency of NBs decreased in the years 2006 and 2007. On the other hand private banks were very consistent over time. These results were supported by Mahesh and Meenakshi (2006).

Insert Table 5 and Insert Figure 1 here

The year wise average profit efficiency of 20 banks in Bangladesh displayed in table 7 and figure 2. From this investigation we observed that the highest average profits efficiency was in 2005 and the inefficiency score was 76.5 percent and in 2001 the profit efficiency was 58.4 percent. In 2007 the profit efficiency increased by 26.36 percent dramatically from 2001. This study contradicted the findings of (Dilruba and Khandakher, 2005; Hamim et al, 2006) in particular for nationalized commercial banks and for Islami Banks. From the figure 2 the over all situation of banks' performance was to be clearly understood. Time has an important affect in reducing profit inefficiency. In case of profit efficiency model the efficiency gradualy increased.

Insert Table 6 and Insert Figure 2 here

Bank wise profits efficiency of 20 banks showed a more clear perception about the performance of an individual bank and the individual profit efficiency portrayed in table 8 and figure 3. The most efficient banks during the study period were found to be Dhaka bank (with 89.9 percent), South East bank (with 87.6 percent), Prime bank (with 85.7 percent), Eastern bank (with 83.8 percent), and Bank Asia (with 77.3 percent). On the contrary, the most inefficient banks during the data period were AB bank (with 35.4 percent), National bank (with 43.2 percent), Sonali bank (with 44.7 percent), and DBBI with (57.4 percent). At the beginning of the study period Uttara bank was most efficient in profits making but it could not retain its position at the end of the period. Opposite scenario observed in case of Islamic banks and during 2001 to 2004 Islamic banks were comparatively less efficient to raise profits level but at the end of the race their growth surprisingly increased. In 2001-2004 the average profit efficiency was around 45 percent and in 2006-2007 it was around 98 percent. Hence Islamic banking system has been enjoying considerable profits efficiency for two years according to this study. Moreover, foreign banks were very much efficient in producing profits making as they were at the top position which was really an alarming threat to the Nationalized Commercial banks (NBs) because reverse situation has been taken place to the NBs.

Insert Table 7 and Insert Figure 3 here

All NBs were inefficient to boost up the profitability. From the inefficiency model of the profit efficiency model we noticed that total assets were highly insignificant. Therefore the conclusion is that Nationalized Commercial Banks should properly handle their total assets make a standard solution to still existing overstaffed even after many years of reforms.

Hypothesis Tests of Profit Efficiency Model

The results of various hypothesis tests of the profit efficiency model were presented in table 5. The all hypothesis tests were obtained using the generalized likelihood-ratio statistic (7).

Insert Table 8 here

The estimates of variance ratios ($\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$) of profit efficiency model is 0.999 indicated that the inefficiency element U_{it} is stochastic. The first null hypothesis is $H_0 : \gamma = 0$, which specify that there is no technical inefficiency effect in the profit efficiency model. The hypothesis is rejected so we can conclude that there is a technical inefficiency effect in the model.

The second null hypothesis is $H_0 : \beta_{ij} = 0$, which specifies that Cobb-Douglas Production Function is more preferable than Translog Production Function. From the result it is observed that the null hypothesis is strappingly rejected and Translog Production Function is more favorable.

The third null hypothesis is $H_0 : \eta = 0$, which specifies that the technical inefficiency effect does not vary considerably over time in the profit efficiency model. The null hypothesis is rejected signifying that the technical inefficiency effect differs significantly.

POLICY RECOMMENDATIONS

Profit efficiency evaluation is useful for individual investment or loan decisions and bank profit efficiency results of banks can help improve their overall investment performance. Bank efficiency studies are of crucial importance for operational and academic proposes (Berger et al., 1997). The findings of the study have important policy implications for efficiently managing the financial institutions, especially the NB, ISB and PB banks. In particular, the NB should take appropriate actions for increasing their coverage in offering innovative technology driven services with a view to increasing their performance and raising their market competitiveness. Studies show that Islamic banks cannot operate with its full efficiency level if it operates under a conventional banking framework, their efficiency goes down in a number of dimensions. Profit efficiency of online banking can be significantly improved by time, total assets, Herfindahl-Hirschman Index because these were observed significant with negative values which represented decreasing the level of inefficiency.

It would be important for financial sector policies to encourage the banks to use any excess liquidity in the banking system for providing credit to productive activities. The Bangladesh Bank, being the regulator of the financial system, can play an important role through taking necessary measures to expedite the initiatives of the traditional banks in adopting such innovative technology driven products and services in their banking activities. On its part, this bank should strengthen its prudential oversight and closely monitor the liquidity situation in the banking system. In addition, it would be important for the Bangladesh Bank to continue its efforts in urging the banks to reduce their lending rates, increase competition among the financial intermediaries, and pursue strong monitoring and supervision measures so that the financial institutions reduce administrative cost by improving efficiency and reducing the burden of nonperforming loans. However, the digital investments through effective extension delivery program in the current political and economic environment in Bangladesh will provide bankers with skills essential to increasing efficiency. Finally, it may be mentioned that if the online banking (financial) system, is to become truly liquid and efficient it must develop more standardized and universally (or at least widely) tradable financial instruments.

CONCLUSION

Efficiency measurement has been the concern of researchers with an aim to look into the efficiency levels of different commercial banks in Bangladesh engaged in various production activities. Identifying determinants of efficiency levels is a major concern in efficiency analysis. This study sets out to provide estimates of bank profit efficiency and to compare efficiency estimates for NBs (National Banks), ISBs (Islamic Banks), FBs (Foreign Banks), and PBs (Private Banks) of Bangladesh banking industries using stochastic frontier analysis. We compared the profit (in) efficiencies of 20 Commercial Banks group wise, year wise and specific bank wise over time period.

The most important results were summarized below:

First, we analyzed the Translog Stochastic Frontier Production Function with distributional assumptions for profit efficiency model and the presence of one-sided error component was justified by the LR test individually, which was highly significant for this model. We found that the profit inefficiency has declined over the reference period and Translog Production Function is more preferable than Cobb-Douglas Production Function.

Second, the most expected result observed in inefficiency model of profit function and the estimated coefficient of time with -0.370 indicated that day by day the level of efficiency was being increased. From the estimated coefficients of inefficiency model it was seen that time, total assets, Herfindahl-Hirschman Index were found significant with negative values represented decreasing the level of inefficiency.

Third, the estimated year wise average efficiencies of the sample banks from the profit model was 0.664 while group wise average technical efficiencies was 0.639. In case of profit efficiency, foreign banks were most efficient (68.8 percent) along with private banks (68.7 percent). From this study it was revealed that Government owned banks were least efficient that increase profit level with 58.4 percent. During the years 2001 to 2004 profits efficiency of nationalized commercial banks were almost stable and it was around 45.8 percent but in the following year efficiency scores increased dramatically and it became doubled with 87.5 percent. Again the efficiency of NBs decreased in the years 2006 and 2007. On the other hand private banks were very consistent in this regard. In terms of profit model, Dhaka Bank is highly efficient with score 0.89 and AB Bank was lowest efficient with score 0.35 according to the sample data. These findings have important policy implications in improving profit efficiency among online banks in Bangladesh.

Acknowledgements:

The authors wish to acknowledge the support provided by Research University Grant Scheme, No. 1001/PJJAUH/811130, Universiti Sains Malaysia, Penang, Malaysia for conducting this research.

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Table 1 List of Online Banks considered in this study.

List of Online Bank's Name	Serial Number
Sonali Bank	1
Janata Bank	2
Islami Bank	3
Shahajal Islami Bank	4
Al Arafah Bank	5
Bank Asia	6
The city Bank	7
National Bank	8
Prime Bank	9
Uttara Bank	10
One Bank	11
UCB Bank	12
Pubali Bank	13
Priemer Bank	14
Mutual Bank	15
South East Bank	16
Eastern Bank	17
AB Bank	18
Dhaka Bank	19
DBBl	20

Table 2 OLS Estimates of Translog Stochastic Frontier Production Function: Profits Frontier

Variables	Parameters	Coefficients	S.E	t-value
Constant	β_0	1.692**	1.693	1.693
Capital	β_1	0.616***	-1.398	-1.398
Material	β_2	0.873*	4.538	4.538
Labor	β_3	0.466*	-2.371	-2.371
Time	β_4	0.179**	1.942	1.942
Capital*Capital	β_{11}	0.212@	-0.029	-0.029
Material*Material	β_{22}	0.355**	-2.303	-2.303
Labor*Labor	β_{33}	0.049@	0.624	0.624
Time*Time	β_{44}	0.023@	0.754	0.754
Capital*Material	β_{12}	0.212@	0.442	0.442
Capital*Labor	β_{13}	0.107@	1.105	1.105
Capital*Time	β_{14}	0.044@	-0.803	-0.803
Material*Labor	β_{23}	0.149@	-0.214	-0.214
Material*Time	β_{24}	0.064**	-2.129	-2.129
Labor*Time	β_{34}	0.030*	2.323	2.323
Sigma-squared	0.25333467			
Log likelihood function	-94.605314			

*,**,*** Significance level at 1%, 5%, 10% consecutively

@ means insignificant, S.E = Standard Error

Table 3 Maximum-Likelihood Estimates of Translog Production Function: Profit Frontier

Variables	Parameters	Coefficients	S.E	t-value
Constant	β_0	5.106*	0.724	7.051
Capital	β_1	-0.696*	0.299	-2.328
Material	β_2	0.887*	0.147	6.031
Labor	β_3	0.062@	0.121	0.509
Time	β_4	0.053@	0.084	0.633
Capital*Capital	β_{11}	0.081*	0.011	7.058
Material*Material	β_{22}	-0.514*	0.151	-3.392
Labor*Labor	β_{33}	0.036***	0.023	1.541
Time*Time	β_{44}	0.029*	0.005	5.831
Capital*Material	β_{12}	0.257*	0.103	2.496
Capital*Labor	β_{13}	-0.048*	0.010	-4.994
Capital*Time	β_{14}	-0.063**	0.028	-2.256
Material*Labor	β_{23}	-0.010@	0.037	-0.256
Material*Time	β_{24}	0.010@	0.034	0.295
Labor*Time	β_{34}	0.036**	0.018	1.977

*,**,*** Significance level at 1 %, 5 %, 10% consecutively

@ means insignificant, S.E = Standard Error

Table 4 Maximum Likelihood Estimates of the Parameters of Inefficiency Effects Model

Variables	**Parameters**	**Coefficients**	**S.E**	**t-value**
Constant	δ_0	2.493*	0.967	2.578
Time	δ_1	-0.370*	0.065	-5.708
Total Assets	δ_2	-0.192***	0.120	-1.604
Herfindahl-Hirschman Index	δ_3	-0.058@	0.213	-0.272
NB Dummy	δ_4	1.404**	0.788	1.782
ISB Dummy	δ_6	1.687*	0.509	3.311
FB Dummy	δ_7	-0.440@	0.829	-0.530
PB Dummy	δ_8	-0.158@	0.513	-0.308
Sigma-squared		0.860*	0.103	8.312
Gamma		.99999*	0.00021	28454.734

*,**,*** Significance level at 1 %, 5 %, 10% consecutively

@ means insignificant, S.E = Standard Error

Table 5 Year Wise Average Profit Efficiency of Banks in Bangladesh

Year	Mean
2001	0.584
2002	0.586
2003	0.609
2004	0.661
2005	0.765
2006	0.705
2007	0.738
Mean	**0.664**

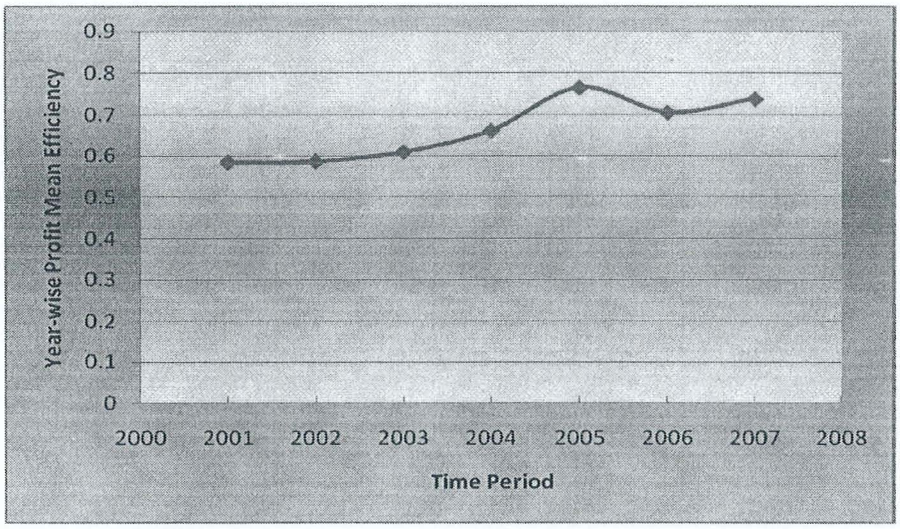

Figure1 Year-wise average profit efficiency over time

Table 6 Year-wise Bank Group Level Profit Mean Efficiency

Year	NB	ISB	FB	PB
2001	0.338	0.567	0.349	0.662
2002	0.463	0.438	0.505	0.651
2003	0.456	0.488	0.700	0.647
2004	0.458	0.396	0.856	0.723
2005	0.875	0.705	0.897	0.741
2006	0.786	0.792	0.762	0.663
2007	0.713	0.816	0.748	0.723
Mean	**0.584**	**0.600**	**0.688**	**0.687**

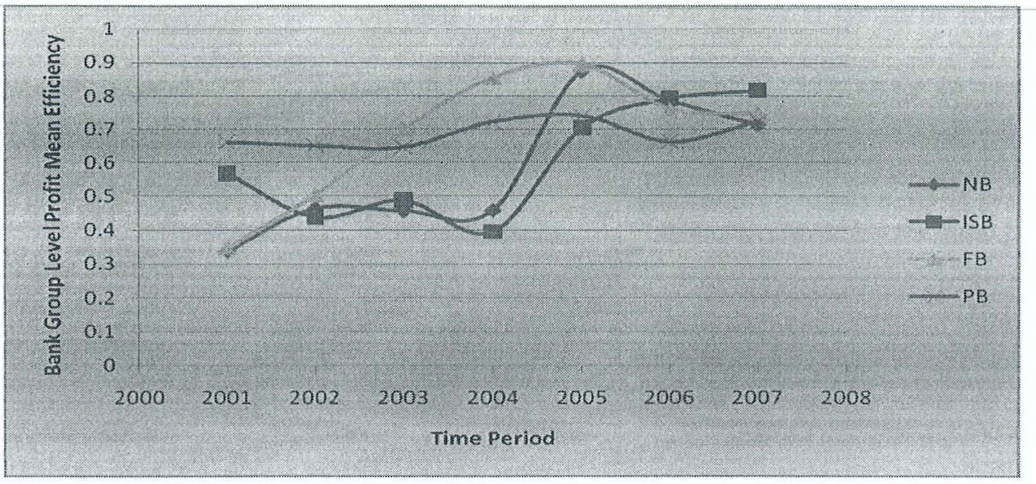

Figure 2 Bank group level profit mean efficiency over time

Table 7 Profit Efficiency of Banks in Bangladesh

Bank's Name	2001	2002	2003	2004	2005	2006	2007	Mean Efficiency
Sonali Bank	0.220	0.382	0.194	0.291	0.987	0.579	0.479	**0.447**
Janata Bank	0.455	0.544	0.718	0.625	0.762	0.993	0.947	**0.721**
Islami Bank	0.266	0.397	0.293	0.468	0.686	0.583	0.797	**0.499**
Shahajal Islami Bank	0.589	0.584	0.599	0.126	0.682	0.867	0.989	**0.634**
Al Arafah Bank	0.846	0.332	0.570	0.594	0.747	0.926	0.661	**0.668**
Bank Asia	0.340	0.542	0.813	0.991	0.978	0.851	0.894	**0.773**
The city Bank	0.357	0.467	0.586	0.720	0.817	0.673	0.602	**0.603**
National Bank	0.607	0.635	0.314	0.318	0.261	0.446	0.443	**0.432**
Prime Bank	0.978	0.838	0.949	0.891	0.966	0.726	0.650	**0.857**
Uttara Bank	0.999	0.812	0.633	0.625	0.724	0.462	0.436	**0.670**
One Bank	0.282	0.477	0.437	0.947	0.865	0.967	0.983	**0.708**
UCB Bank	0.605	0.504	0.713	0.845	0.923	0.778	0.906	**0.753**
Pubali Bank	0.809	0.801	0.512	0.331	0.595	0.543	0.692	**0.612**
Priemer Bank	0.388	0.543	0.635	0.987	0.771	0.620	0.515	**0.637**
Mutual Bank	0.360	0.560	0.933	0.922	0.888	0.797	0.608	**0.724**
South East Bank	0.991	0.843	0.756	0.749	0.895	0.895	1.000	**0.876**
Eastern Bank	0.961	0.885	0.935	0.944	0.756	0.698	0.690	**0.838**
AB Bank	0.112	0.113	0.166	0.303	0.511	0.340	0.933	**0.354**
Dhaka Bank	0.994	0.965	0.926	0.932	0.819	0.725	0.935	**0.899**
DBBl	0.525	0.491	0.503	0.602	0.665	0.624	0.606	**0.574**

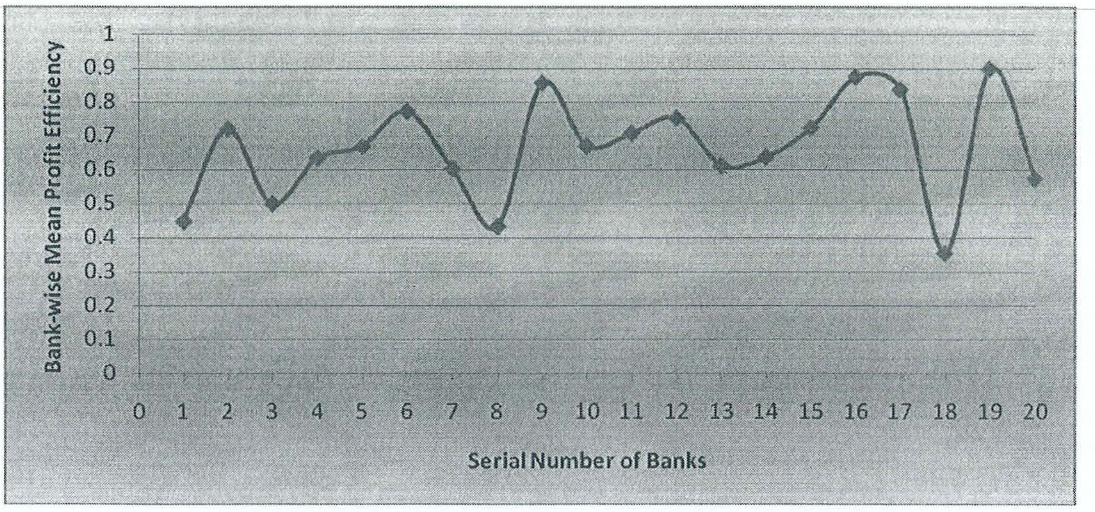

Figure 3 Bank-wise Profit mean efficiency in Bangladesh

Table 8 Generalized Likelihood-Ratio Test of Hypothesis of the Stochastic Profit Frontier Production Model

NULL HYPOTHESIS	LOG-LIKELIHOOD FUNCTION	TEST STATISTIC λ	CRITICAL VALUE*	DECISION
$H_0 : \gamma = 0$	-94.59	107.77	3.38	Reject H_0
$H_0 : \beta_{ij} = 0$	-12.21	24.39	19.35	Reject H_0
$H_0 : \eta = 0$	-40.65	81.29	3.38	Reject H_0

Notes: All critical values are at 5% level of significance.

*The critical value are obtained from table of Kodde and Palm (1986). The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution , because the restriction defines a point on the boundary of parameter space.

International Journal of the Physical Sciences Vol. 6(7), pp. 1851-1862, 4 April, 2011
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Optimal control of inventory-production systems with gumbel distributed deterioration

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Accepted 7 March, 2011

This paper is concerned with the development of an inventory-production model for a special class of generalized extreme value, that is, gumbel distributed deterioration items. The production system with inventory-level-dependent demand is considered and Pontryagin maximum principle is used to determine the optimal control, which is the production rate that minimizes the optimal control model, while satisfying the system dynamics. The necessary optimality conditions are also derived in this case. It is then illustrated with the help of examples.

Key words: Inventory-production systems, gumbel distributed deterioration, optimal control, pontryagin maximum principle.

INTRODUCTION

Inventory problems for deteriorating items and the variations in the demand rate with time have been studied extensively by many researchers from time to time. This type of research started with the work of Whitin (1957) who considered the deterioration of the fashion goods at the end of a prescribed shortage period. Importance of items deteriorating in inventory modeling is now widely acknowledged and has received a lot of attention (Raafat, 1991; Shah and Shah, 2000; Goyal and Giri, 2001). A reasonable model of an inventory system was developed by Ghare and Schrader (1963), considering the inventory depletion not only by demand but also by item's deterioration. Their observation led to the modeling of the inventory items with decaying processes by the differential equation:

$$\frac{dx(t)}{dt}+\theta x(t)=-y(t),$$

where θ is the constant decay rate, $x(t)$ is the inventory level at time t, and $y(t)$ is the demand rate at time t.

This paper develops an optimal control model and utilizes Pontryagin maximum principle by Pontryagin et al. (1962) to derive the necessary optimality conditions for inventory-production systems, which, to the best of our knowledge, is an optimal control theory that has never been applied in conjunction with a special class of generalized extreme value, which is, gumbel distributed deterioration items. During the last two decades, various researches attacked on inventory-production problem with the application of optimal control theory. It has been successfully applied in production planning when only deterioration items were involved (Bounkhel and Tadj, 2005; Bounkhel et al., 2005; Tadj et al., 2006; Benhadid et al., 2008; Awad et al., 2009). In this context, a few researches are found for Weibull distributed deterioration items (Ghosh and Chaudhuri, 2004; Al-khedhairi and Tadj, 2007; Baten and Kamil, 2009) for Pareto distribution deterioration rate (Srinivasa et al., 2005, 2007; Baten and Kamil, 2010). But no attempt has been made to develop the inventory model as an optimal control model and to derive an explicit solution of an inventory model with gumbel distribution deterioration using Pontryagin maximum principle. The continuous review policy of optimal control approach is to be novel in this framework. There seems to be no literature on the optimal control of continuous review manufacturing systems with this

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gumbel distribution deterioration items rate.

The novelty we take into consideration in this study is that, the time of deterioration is a random variable followed by three-parameter generalized extreme value distribution. The probability density function of a generalized extreme value distribution having probability distribution of the form:

$$f(t) = \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}^{\xi+1}\exp\{-\exp\{-(t-\mu)/\sigma\}^{\xi+1}\}$$

where $\mu \in R$ is the location parameter and $\sigma \in (0,\infty)$ is the scale parameter and $\xi \in (-\infty,\infty)$ is the shape parameter.

The shape parameter ξ governs the tail behavior of the distribution. The family defined by $\xi \to 0$ corresponds to a special case of generalized extreme value distribution, that is, Gumbel distribution. This distribution can be used to model either maximum or minimum rate of deterioration. The probability density function and probability distribution function of Gumbel corresponds to a special class of extreme (here maximum) value distribution

$$f_{\max}(t) = \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\exp\{-\exp\{-(t-\mu)/\sigma\}\}, \quad t>0,$$

and

$$F_{\max}(t) = 1-\exp\{-\exp\{-(t-\mu)/\sigma\}\}, \quad t>0$$

respectively.

The instantaneous rate of deterioration of Gumbel distribution corresponds to a maximum value of the on-hand inventory and is given by:

$$\theta(t) = \frac{f_{\max}(t)}{1-F_{\max}(t)} = \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}, \quad t>0.$$

In developing inventory models, continuous-time models of time-varying demands have been considered in this study. The time of deterioration rate is assumed to follow Gumbel distribution as well as a non-negative discount rate is considered for the inventory-production systems. We assume that all the functional forms are non-negative continuous and differentiable on $[0,\infty]$.

This paper develops a first model in which the dynamic demand is a function of time. We then extend this first model to an even more general model in which items deterioration are taken into account which refer to a special class of generalized extreme value, which is, Gumbel distribution. The paper also derives explicit optimal policies for the inventory models where items are deteriorating with this type of Gumbel distribution that can be used in the decision making process.

MATERIALS AND METHODS

Model without item deterioration and notations

We assume that an inventory goal level and a production goal rate are set, and penalties are incurred when the inventory level and the production rate deviate from these goals. We introduce the following notations to write the optimal control model:

q: Inventory holding cost incurred for the inventory level to deviate from its goal.
r: Production unit cost incurred for the production rate to deviate from its goal.
$\hat{x}(t)$: Inventory goal level.
$\hat{u}(t)$: Production goal rate.
$\rho \geq 0$: Constant non-negative discount rate.

We want to keep the inventory $x(t)$ as close as possible to its goal $\hat{x}(t)$, and also keep the production rate $u(t)$ as close to its goal level $\hat{u}(t)$. The quadratic terms $q[x(t)-\hat{x}(t)]^2$ and $r[u(t)-\hat{u}(t)]^2$ impose 'penalties' for having either x or u not being close to its corresponding goal level.

The optimal control model can be expressed as the quadratic form that we need to minimize

$$\text{minimize} \quad J(u,x,\hat{u}) = \frac{1}{2}\int_0^T e^{-\rho t}\left\{q[x(t)-\hat{x}(t)]^2 + r[u(t)-\hat{u}(t)]^2\right\}dt \tag{1}$$

subject to the dynamics of the inventory level of the state equation which says that the inventory at time t is increased by the production rate $u(t)$ and decreased by the demand rate $y(t)$ can be written as:

$$dx(t) = [u(t) - y(t)]dt \tag{2}$$

with initial condition $x(T) = 0$ and the non-negativity constraint

$$u(t) \geq 0, \quad \text{for all } t \in [0,T] \tag{3}$$

where the fixed length of the planning horizon is T, $x(t)$: inventory level function at any instant of time $t \in [0,T]$, $u(t)$: production rate at any instant of time $t \in [0,T]$ and $y(t)$: demand rate at any instant of time $t \in [0,T]$.

The current-value Hamiltonian of the model is defined as

$$H(t,x(t),u(t),\hat{u}(t),\gamma(t))$$
$$=-\frac{1}{2}\int_0^T e^{-\rho t}\left\{q[x(t)-\hat{x}(t)]^2+r[u(t)-\hat{u}(t)]^2\right\}+\gamma(t)[u(t)-y(t)] \quad (4)$$

Model with item deterioration

Consider a system where items, subject to Gumbel distributed deterioration, corresponds to a special class of extreme value distribution. For $t \geq 0$, let $\theta(t) = \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}$ be the deterioration rate at the inventory level $x(t)$ at time t. Keeping same notation and the same optimal control model as in the previous section, the dynamics of the inventory level of the state equation which says that the inventory at time t is increased by the production rate $u(t)$ and decreased by the demand rate $y(t)$ and the rate of deterioration $\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}$ of Gumbel distribution corresponds to a special class of extreme value distribution can be written as according to

$$dx(t) = [u(t)-y(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x(t)]dt \quad (5)$$

with initial condition $x(T)=0$ and the non-negativity constraint $u(t) \geq 0, \quad \text{for all } t \in [0,T]$.

The current-value Hamiltonian of the model is defined as

$$H(t,x(t),u(t),\hat{u}(t),\gamma(t))$$
$$=-\frac{1}{2}\int_0^T e^{-\rho t}\left\{q[x(t)-\hat{x}(t)]^2+r[u(t)-\hat{u}(t)]^2\right\}+\gamma(t)\left[u(t)-y(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x(t)\right] \quad (6)$$

RESULTS

Development of the optimal control models

Let us consider a manufacturing firm, producing a single product, selling some and stocking the rest in a warehouse. We assume that the production deteriorates while in stock and the demand rate varies with time. The firm has set an inventory goal level and production goal rate. Since the constraint $u(t)-y(t) \geq 0, \quad \text{for all } t \in [0,T]$ with the state equation x is nondecreasing. Therefore, shortages are not allowed in this study.

Define the variables $z(t), \tilde{z}(t)\ and\ \eta(t)$ such that:

$$z(t) = x(t) - \hat{x}(t), \quad (7) \quad \tilde{z}(t) = u(t) - \hat{u}(t), \quad (8)$$

$$\text{and } \eta(t) = \hat{u}(t) - y(t) - \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}(t). \quad (9)$$

Adding and subtracting the last term $\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}(t)$ from the right hand side of Equation (9) to Equation (5) and rearranging the terms, we have:

$$d(x(t)-\hat{x}(t)) = [-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}(x(t)-\hat{x}(t))+u(t)-y(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}(t)]dt.$$

Hence by Equation (7)

$$dz(t)=[-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}z(t)+u(t)-y(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}(t)]dt. \quad (10)$$

Now, substituting Equations (8) and (9) in (10) yields:

$$dz(t) = [-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}z(t)+\tilde{z}(t)+\eta(t)]dt. \quad (11)$$

The optimal control model (1) becomes:

$$\text{minimize} \quad J(z,\tilde{z}) = \frac{1}{2}\int_0^T e^{-\rho t}\{q[z(t)^2]+r[\tilde{z}(t)^2]\}dt \quad (12)$$

subject to an ordinary differential Equation (11) and the non-negativity constraint $\tilde{z}(t) \geq 0, \quad \text{for all } t \in [0,T]$.

By the virtue of (2), the instantaneous state of the inventory level $x(t)$ at any time t is governed by the differential equation:

$$\frac{dx(t)}{dt} = u(t) - y(t), \quad 0 \leq t \leq T, \quad x(T) = 0 \quad (13)$$

The boundary conditions with Equation (13) are: at $x(0)=0, x(T)=0$

$$x(t) = [u(t) - y(t)]t, \quad \text{for } 0 \leq t \leq T. \quad (14)$$

Assuming that $x(0)=x$ is known and note that the production goal rate $\hat{u}(t)$ can be computed using the state Equation (13) as:

$$\hat{u}(t) = y(t) \quad (15)$$

By the virtue of Equation (5), the instantaneous state of the inventory level $x(t)$ at any time t is governed by the differential equation:

$$\frac{dx(t)}{dt}+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x(t)=u(t)-y(t), \quad 0\leq t\leq T, \quad x(T)=0 \quad (16)$$

This is a linear ordinary differential equation of first order and its integrating factor is:

$$=\exp\{\int \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}dt\}=\exp\left[\exp\{-(t-\mu)/\sigma\}\right].$$

Multiplying both sides of Equation (16) by $\exp\left[\exp\{-(t-\mu)/\sigma\}\right]$ and then integrating over $[0,T]$, we have:

$$x(t)\exp\left[\exp\{-(t-\mu)/\sigma\}\right]-x(0)=-\int_0^T[y(t)-u(t)]\exp\left[\exp\{-(t-\mu)/\sigma\}\right]dt. \quad (17)$$

Substituting this value of $x(0)$ in Equation (16), we obtain the instantaneous level of inventory at any time $t\in[0,T]$ is given by

$$x(t)=\frac{\int_0^{t_1}[y(t)-u(t)]\exp\left[\exp\{-(t-\mu)/\sigma\}\right]dt-\int_0^{T}[y(t)-u(t)]\exp\left[\exp\{-(t-\mu)/\sigma\}\right]dt}{\exp\left[\exp\{-(t-\mu)/\sigma\}\right]}.$$

Solving the differential equation, the on-hand inventory at time t is obtained as

$$x(t)=x(0)\exp\left[\exp\{-(t-\mu)/\sigma\}\right]-\int_0^T[y(t)-u(t)]dt \quad 0\le t\le T. \quad (18)$$

Assuming that $x(0)=x$ is known and note that the production goal rate $\hat{u}(t)$ can be computed using the state Equation (16) as:

$$\hat{u}(t)=y(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}(t) \quad (19)$$

Solution to the optimal control models

In order to solve the optimal control model (1) subject to state Equations (2) and (5), we derive the necessary optimality conditions using Pontryagin maximum principle developed by Pontryagin (1962), also, Sethi and Thompson (2000).

Solution of the optimal control model without item deterioration

The optimal control approach consists in determining the optimal control $\hat{u}(t)$ that minimizes the optimal control model (1) subject to the state Equation (2). By the maximum principle of Pontryagin (1962), there exists adjoint function $\gamma(t)$ such that the Hamiltonian functional form (4) satisfies the control equation:

$$\frac{\partial}{\partial u(t)}H\left(t,x(t),u(t),\hat{u}(t),\gamma(t)\right)=0, \quad (20)$$

the adjoint equation

$$\frac{\partial}{\partial x(t)}H\left(t,x(t),u(t),\hat{u}(t),\gamma(t)\right)=-\frac{d}{dt}\gamma(t), \quad \gamma(T)=0 \quad (21)$$

and the state equation

$$\frac{\partial}{\partial \gamma(t)}H\left(t,x(t),u(t),\hat{u}(t),\gamma(t)\right)=\frac{d}{dt}x(t), \quad x(0)=0. \quad (22)$$

Then the control Equation (20) is equivalent to:

$$u(t)=\hat{u}(t)+\frac{e^{\rho t}}{r}\gamma(t). \quad (23)$$

The adjoint Equation (21) is equivalent to:

$$\frac{d}{dt}\gamma(t)=qe^{-\rho t}\left[x(t)-\hat{x}(t)\right], \quad (24)$$

and the state Equation (22) is similar to (2).

Substitution expression (23) into the state Equation (2) yields

$$\frac{d}{dt}x(t)=\hat{u}(t)+\frac{\gamma(t)e^{\rho t}}{r}-y(t). \quad (25)$$

From Equation (25) we have

$$\frac{\gamma(t)e^{\rho t}}{r}=\frac{d}{dt}x(t)-\hat{u}(t)+y(t). \quad (26)$$

By differentiating Equation (25), we obtain:

$$\frac{d^2}{dt^2}x(t)=\frac{d}{dt}\hat{u}(t)-\frac{d}{dt}y(t)+\frac{1}{r}\left[e^{\rho t}\frac{d}{dt}\gamma(t)+\rho\gamma(t)e^{\rho t}\right]. \quad (27)$$

Substitution expression (24) into Equation (27) yields

$$\frac{d^2}{dt^2}x(t)=\frac{d}{dt}\hat{u}(t)-\frac{d}{dt}y(t)+\frac{q}{r}\left[x(t)-\hat{x}(t)\right]+\frac{\rho}{r}e^{\rho t}\gamma(t). \quad (28)$$

Finally, substituting expression (26) into (28) to Obtain

$$\frac{d^2}{dt^2}x(t)-\frac{q}{r}x(t)=\frac{d}{dt}\hat{u}(t)-\frac{d}{dt}y(t)-\frac{q}{r}\hat{x}(t)+\rho[y(t)-\hat{u}(t)]. \quad (29)$$

Since a closed form solution is not possible, so this boundary value problem can be solvednumerically together with initial condition $x(0)=0$ and the terminal condition $\gamma(T)=0.$

Solution of the optimal control model with item deterioration

The optimal control approach consists in determining the optimal control $\hat{u}(t)$ that minimizes the optimal control model (1) subject to the state Equation (5). By the maximum principle of Pontryagin (1962), there exists adjoint function $\gamma(t)$ such that the Hamiltonian functional form (6) satisfies the necessary conditions (20), (21) and (22). Then, here, the control Equation (20) is equivalent to (23) also.

The adjoint Equation (21) is equivalent to:

$$\frac{d}{dt}\gamma(t)=\left[qe^{-\rho t}+\gamma(t)\exp\{-(t-\mu)/\sigma\}\right]-qe^{-\rho t}\hat{x}(t), \quad (30)$$

And the state Equation (22) is similar to (5).

Substituting expression (23) into the state Equation (5) yields

$$\frac{d}{dt}x(t)=\hat{u}(t)+\frac{\gamma(t)e^{\rho t}}{r}-y(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x(t), \quad (31)$$

From Equation (31) we have

$$\frac{\gamma(t)e^{\rho t}}{r}=\frac{d}{dt}x(t)-\hat{u}(t)+y(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x(t). \quad (32)$$

By differentiating (31), we obtain

$$\frac{d^2}{dt^2}x(t)=\frac{d}{dt}\hat{u}(t)-\frac{d}{dt}y(t)+\frac{1}{r}\left[e^{\rho t}\frac{d}{dt}\gamma(t)+\rho\gamma(t)e^{\rho t}\right]-\exp\{-(t-\mu)/\sigma\}\{-(t-\mu)/\sigma\}. \quad (33)$$

Substituting expression (30) into the Equation (33) yields

$$\frac{d^2}{dt^2}x(t)=\frac{d}{dt}\hat{u}(t)-\frac{d}{dt}y(t)+\frac{q}{r}[x(t)-\hat{x}(t)]+\frac{1}{r}e^{\rho t}\gamma(t)\left[x(t)\exp\{-(t-\mu)/\sigma\}+\rho\right]$$
$$-\exp\{-(t-\mu)/\sigma\}\{-(t-\mu)/\sigma\}. \quad (34)$$

Finally, substituting expression (32) into (34) to obtain

$$\frac{d^2}{dt^2}x(t)-\left[\frac{q}{r}+\frac{\gamma(t)}{r}e^{\rho t}\exp\{-(t-\mu)/\sigma\}-\exp\{-(t-\mu)/\sigma\}\right]x(t)$$
$$=\frac{d}{dt}\hat{u}(t)-\frac{d}{dt}y(t)-\frac{q}{r}\hat{x}(t)+\rho[y(t)-\hat{u}(t)]. \quad (35)$$

Since a closed form solution is not possible, this boundary value problem can be solved numerically together with initial condition $x(0)=0$ and the terminal condition $\gamma(T)=0.$

DISCUSSION

Illustrative examples

In order to present illustrative examples of the results obtained, we use the following parameters where the planning horizon has length T=12 months, $\rho=0.001,$ the inventory holding cost coefficient $q=5$ the production cost coefficient $r=5.$ The goal inventory level is considered $\hat{x}(t)=1+t+\sin(t),$ and the location and scale parameters of the Gumbel distribution rate are considered as $\mu=1$ and $\sigma=1$ respectively. Then the deterioration rate of Gumbel distribution becomes $\theta(t)=\exp\{-(t-1)\}, \quad t\in[0,T].$

Numerical examples are given for different cases of demand rates.

1. Demand rate is constant: $y(t)=y=20,$
2. Demand rate is linear function of time: $y(t)=y_1(t)\,t+y_2(t)=t+15,$
3. Demand rate is quadratic function of time: $y(t)=30+0.1t+0.001t^2.$
4. Demand is sinusoidal function of time: $y(t)=1+\sin(t).$
5. Demand is co-sinusoidal function of time: $y(t)=1+\cos(t).$
6. Demand is exponential increasing function of time: $y(t)=\exp(t).$
7. Demand is exponential decreasing function of time: $y(t)=\exp(-t).$

The inventory level $x(t)$ in-terms of the first-order differential equation from (5) and the second-order differential Equation (35) considering the above demand functions are solved numerically using the version 6.5 of the mathematical package MATLAB.

The constant demand rate is assumed to have fixed value 20 units per unit time. Note that here demand and deterioration does not decrease the inventory level displayed in Figure 1. From Figure 2, it is clear that the production rate is following the constant demand rate. In case of linear demand, it is the form $y_2(t)=t+15.$ The inventory level x(t) in-terms of the first-order differential equation in terms of linear demand is displayed in Figure 3. The result is shown in Figure 4 and it is found that the

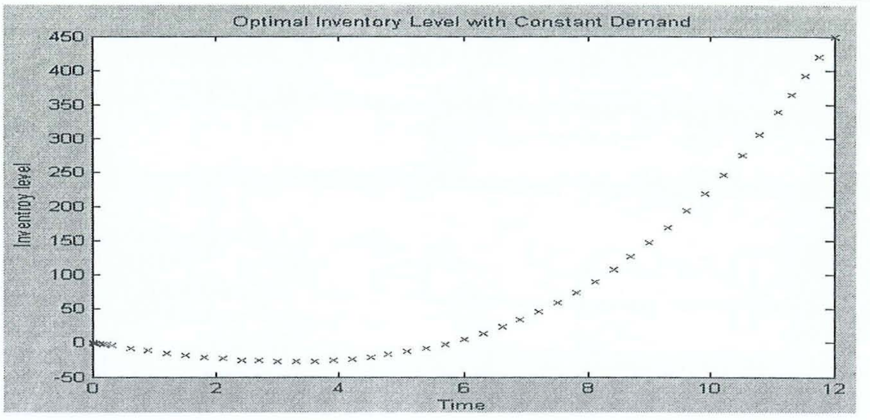

Figure 1. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of constant demand.

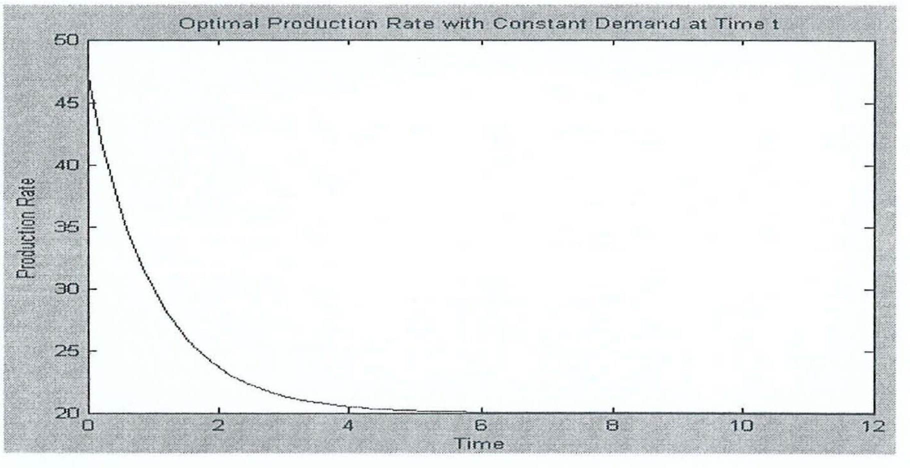

Figure 2. Optimal production policy with constant demand.

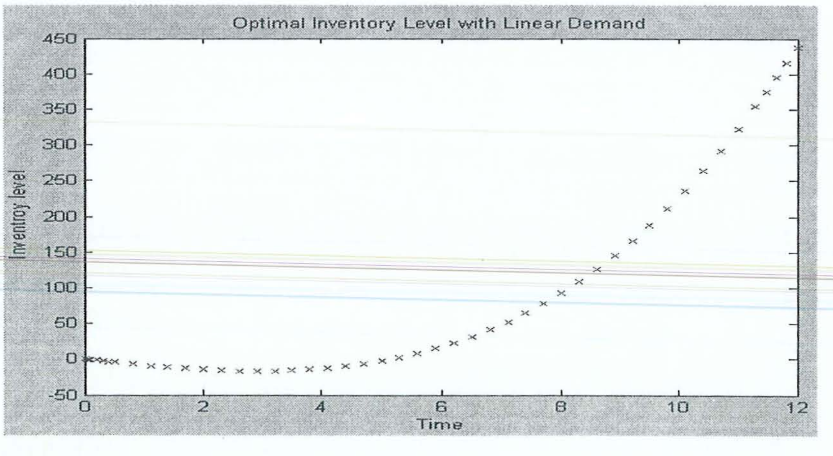

Figure 3. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of linear demand.

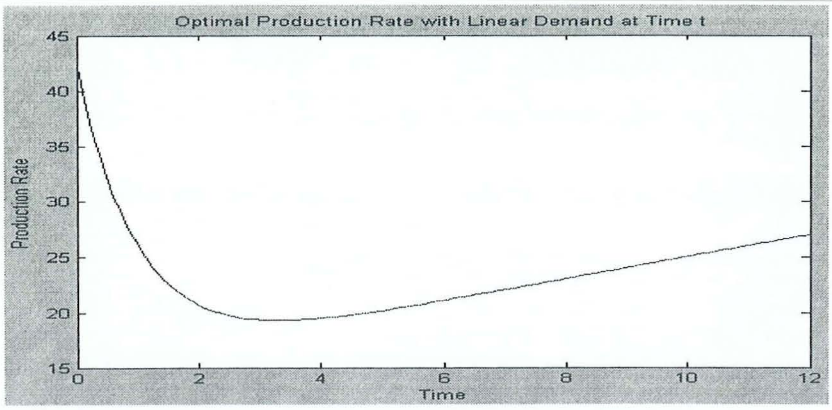

Figure 4. Optimal production policy with linear demand.

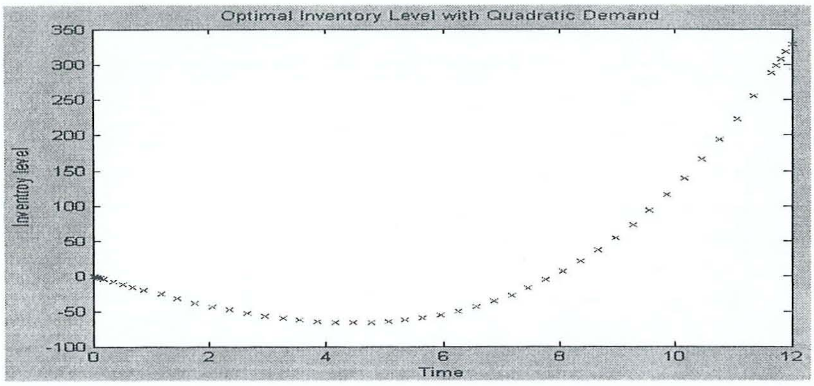

Figure 5. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of quadratic demand.

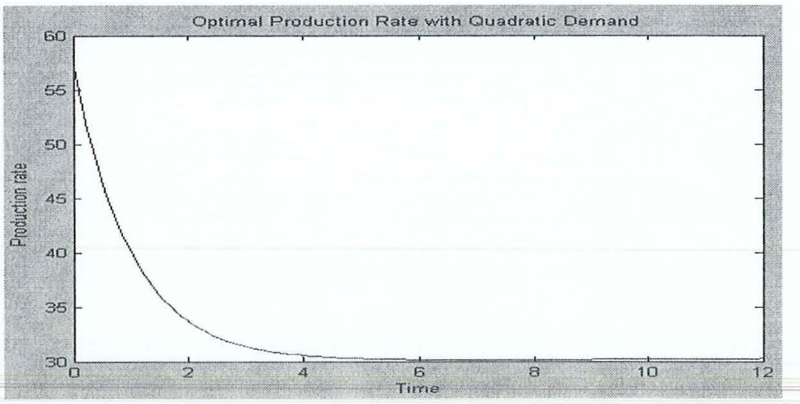

Figure 6. Optimal production policy with quadratic demand.

production rate is following the linear demand rate. The production rate starts with quite large amount due to the large desired production rate. The inventory level x(t) in-terms of the first-order differential equation in terms of quadratic demand is revealed by Figure 5. From Figure 6, it is displayed that the production rate tracks the quadratic demand. The inventory is again increasing because the initial production which is a function of

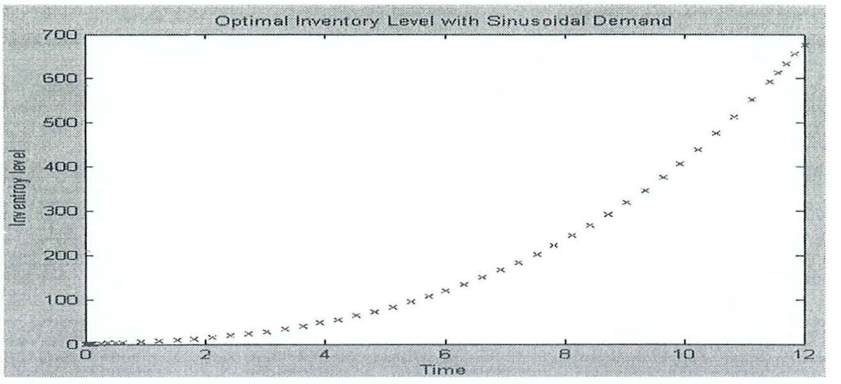

Figure 7. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of sinusoidal demand.

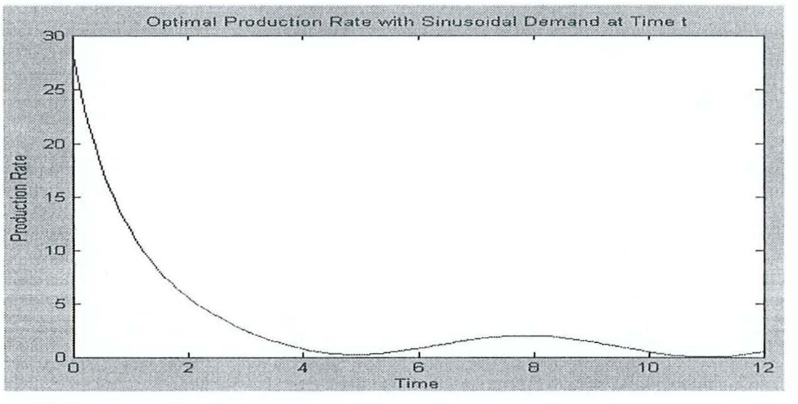

Figure 8. Optimal production policy with sinusoidal demand.

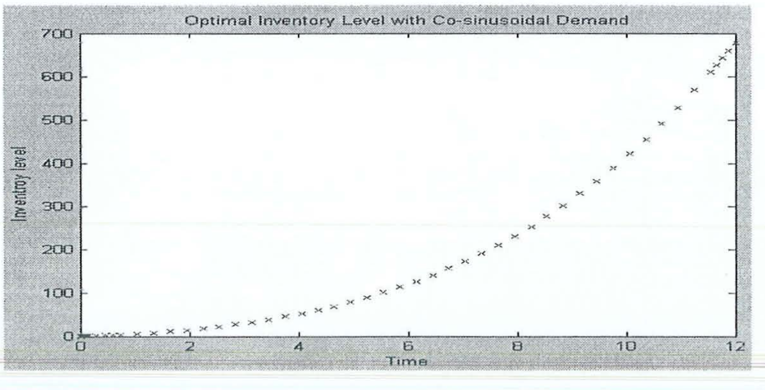

Figure 9. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of co-sinusoidal demand.

desired production rate is high.

Figures 7 to 9 show the slight variations of the inventory and optimal production level with time with changing the shape of the demand functions. In case of sinusoidal, co-sinusoidal and exponential decreasing demand oriented optimal inventory levels over time

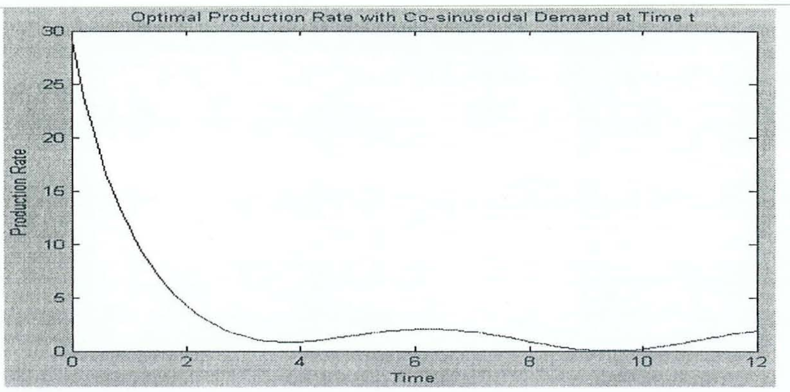

Figure 10. Optimal production policy with co-sinusoidal demand.

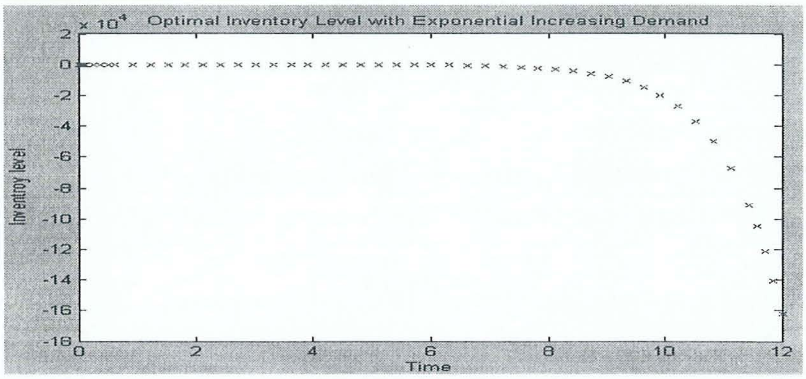

Figure 11. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of exponential increasing demand.

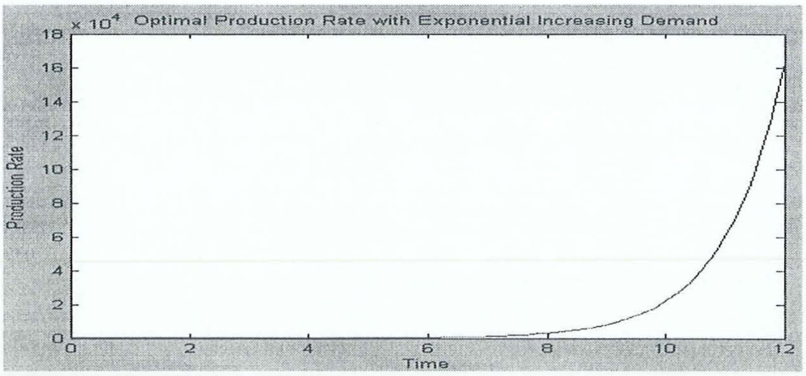

Figure 12. Optimal production policy with exponential increasing demand.

almost have no variations that support the findings of Baten and Kamil (2009). It is observed that the optimal production rates are not very sensitive to changes in the demand functions in case of Gumbel distribution. Optimal production policy with co-sinusoidal demand was shown by Figure 10. On the other hand, Figures 11 and 13 show the large variations of the optimal inventory level with time with changing the shape of the demand functions. From Figures 12 and 14, it is observed that the optimal production rates are very sensitive to changes in the

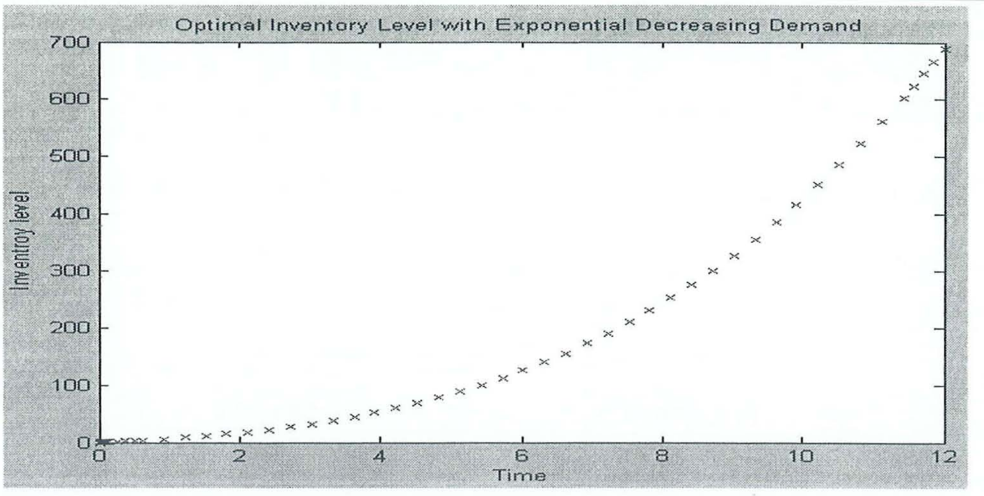

Figure 13. The inventory level $x(t)$ in-terms of the first-order differential equation in terms of exponential decreasing demand.

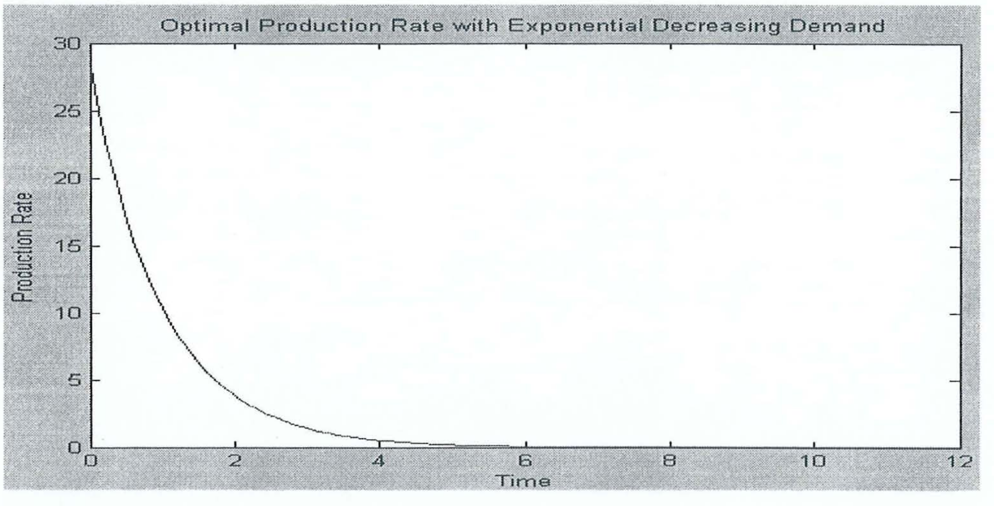

Figure 14. Optimal production policy with exponential decreasing demand.

demand functions. The similar results also available in case of Pareto distributed deterioration study of Baten and Kamil (2010).

The solution of the second-order differential equation is represented by Figure 15 and shows the state of optimal inventory level is increasing.

However, in further discussions, we present the model to measure the performance using different demand patterns. The production level with time t given $\hat{u}(t)$ from the Equation (19) considering the mentioned above different demand rates and we take the inventory goal level is as $\hat{x}(t)=10$ keeping all other parameters unchanged.

Constant demand function

Here, we present the model with constant demand function. Substituting constant $y_1(t)=y_1=20$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_1(t)}{dt}=u_1(t)-y_1(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_1(t), \quad 0\le t\le T, \quad x(T)=0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0)=x$) as:

$$\hat{u}_1(t)=y_1(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_1(t).$$

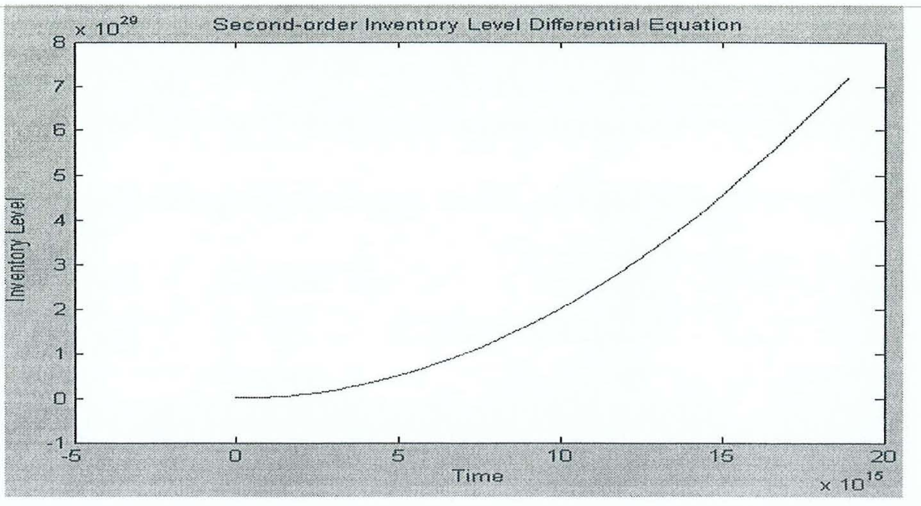

Figure 15. The inventory level $x(t)$ in-terms of the second-order differential equation.

Linear demand function

Here, we present the model with linear demand function. Substituting linear $y_2(t)=t+15$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_2(t)}{dt}=u_2(t)-y_2(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_2(t),\quad 0\le t\le T,\quad x(T)=0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0)=x$) as:

$$\hat{u}_2(t)=y_2(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_2(t).$$

Quadratic demand function

Here, we present the model with linear demand function. Substituting Quadratic $y_3(t)=30+0.1t+0.001t^2$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_3(t)}{dt}=u_3(t)-y_3(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_3(t),\quad 0\le t\le T,\quad x(T)=0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0)=x$) as:

$$\hat{u}_3(t)=y_3(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_3(t).$$

Sinusoidal demand function

Here, we present the model with sinusoidal demand function. Substituting $y_4(t)=1+\sin(t)$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_4(t)}{dt}=u_4(t)-y_4(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_4(t),\quad 0\le t\le T,\quad x(T)=0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0)=x$) as:

$$\hat{u}_4(t)=y_4(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_4(t).$$

Co-sinusoidal demand function

Here, we present the model with sinusoidal demand function. Substituting $y_5(t)=1+\cos(t)$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_5(t)}{dt}=u_5(t)-y_5(t)-\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_5(t),\quad 0\le t\le T,\quad x(T)=0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0)=x$) as:

$$\hat{u}_5(t)=y_5(t)+\frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_5(t).$$

Exponential increasing demand function

Here, we present the model with sinusoidal demand function. Substituting $y_6(t) = \exp(t)$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_6(t)}{dt} = u_6(t) - y_6(t) - \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_6(t), \quad 0 \le t \le T, \quad x(T) = 0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0) = x$) as:

$$\hat{u}_6(t) = y_6(t) + \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_6(t).$$

Exponential decreasing demand function

Here, we present the model with sinusoidal demand function. Substituting $y_6(t) = \exp(-t)$ instead of $y(t)$ in the controlled system we have:

$$\frac{dx_7(t)}{dt} = u_7(t) - y_7(t) - \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}x_7(t), \quad 0 \le t \le T, \quad x(T) = 0$$

from which the production goal rate $\hat{u}(t)$ can be computed (assuming $x(0) = x$) as:

$$\hat{u}_7(t) = y_7(t) + \frac{1}{\sigma}\exp\{-(t-\mu)/\sigma\}\hat{x}_7(t).$$

Conclusion

In this paper, we developed an optimal control model in inventory-production system with a special class of generalized extreme value, which is, Gumbel distribution deteriorating items. This paper derived the explicit solution of the optimal control models of an inventory-production system under a continuous review-policy using Pontryagin maximum principle. However, we gave numerical illustrative examples and numerical solution of optimal inventory-production system with Gumbel distribution deteriorating items using different types of demand functions.

ACKNOWLEDGEMENT

The authors wish to acknowledge the support provided by Research University Grant Scheme, No.101/PJJAUH/811130, Universiti Sains Malaysia, Penang, Malaysia for conducting this research.

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African Journal of Biotechnology Vol. 9(25), pp. 3808-3816, 21 June, 2010
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2010 Academic Journals

Full Length Research Paper

Productive efficiency of tea industry: A stochastic frontier approach

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Accepted 31 May, 2010

In an economy where recourses are scarce and opportunities for a new technology are lacking, studies will be able to show the possibility of raising productivity by improving the industry's efficiency. This study attempts to measure the status of technical efficiency of tea-producing industry for panel data in Bangladesh using the stochastic frontier production function, incorporating technical inefficiency effect model. It was observed that Translog Production Function is more preferable than Cobb-Douglas Production Function. The study estimates that the average technical efficiency of tea producing industries in Bangladesh is 59%. Therefore, the results indicated that there is a great potential exists for tea industry to further increase the value added by 41% using the available input, technology and efficiency improvement, thereby reducing the cost of production. The study identifies that the mean efficiency of tea industries for value added vary among the regions and year-wise mean efficiency seems to be unstable during the study period and therefore, continued efforts to update technologies and equipment are required in pursuit of efficiency in tea industry.

Key words: Technical efficiency, stochastic frontier, translog production, likelihood ratio test, tea industry.

INTRODUCTION

The tea producing industry has been traditionally regarded as one of the major agro-based labor intensive industry and occupies an important role in the national economy of Bangladesh. The role of Bangladesh tea industry in global context is insignificant. It is only 1.68% of the global tea production and 0.58% of the world tea export. It seems that its export is gradually declining. If this trend continues, Bangladesh will turn into a tea importing country by 2015 (Monjur, 2004; Mahmud, 2004). As a result, international comparisons of the tea industry's efficiency have been of great interest to firms in the industry as well as policymakers. The large tea producing countries like India and Sri Lanka produce more than Bangladesh, where India and Sri Lanka's production level is 16 and 12 times higher than Bangladesh (BCS, 1997 - 98). It was found that in 1998, on an average only 1,145 kg of tea was produced per hectare in Bangladesh. Whereas, in the same year, production level per hectare in India and Sri Lanka was 1708 and 2030 kg, respectively (Majumder, 2003).

The concept of the technical efficiency of firms has been pivotal for the development and application of econometric models of frontier functions. Although technical efficiency may be defined in different ways [see, example, Fare et al. (1985)], we consider the definition of the technical efficiency of a given firm (at a given time period) as the ratio of its mean production (conditional on its levels of factor inputs and firm effects) to the corresponding mean production if the firm utilized its levels of inputs most efficiently [see Battese and Coelli, 1988]. Efficiency is an important factor of productivity growth as well as stability of production in developing agricultural economics. In view of slow growth and increasing instability in tea production in Bangladesh (Monjur, 2004), the tea economy of Bangladesh is expected to be benefited to a great extent from the study on technical efficiency studies. Estimates on the extent of inefficiencies could help decide whether to improve efficiency or to develop new technology to raise tea productivity in Bangladesh.

There are some studies that have been carried out to analysis for the measurement of efficiency of tea industries.

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They include among others: Hazarika and Subramanian (1999) for Asam tea industry in India; Ariyawardana (2003) for value added tea producers in Sri Lanka; Basnayake and Gunaratne (2002), and Rohan Jayatilake (2009) for tea small holdings in Sri Lanka; Baten et. el. (2009) for seven tea regions of Bangladesh; and Nghia Dai Tran (2009) for different tea production systems in Thai Nguyen Province. Besides Daniela et al. (2008), and Fahr and Sunde (2005) investigated empirically the spatial variation of productivity across Brazilian regions applying stochastic frontier analysis to manufacturing data. Haque (2006, 2007) examined and compared the value chain models that are adopted by the tea industries of Bangladesh and Japan using some descriptive statistics analysis. These studies do not adopt a stochastic frontier model, which is generally thought as an essential for productivity analysis and for measuring technical efficiency of tea industry.

The stochastic frontier production function, which was independently proposed by Aigner et al. (1977), Meeusen and van den Broeck (1977) has been a significant contribution to the econometric modeling of production and the estimation of technical efficiency of firms. The stochastic frontier involved two random components, one associated with the presence of technical inefficiency and the other being a traditional random error. Applications of frontier functions have involved both cross-sectional and panel data. These studies have made a number of distributional assumptions for the random variables involved and have considered various estimators for the parameters of these models. Survey papers on frontier functions have been presented by Forsoud et al. (1980), Schmidt (1986), Bauer (1990) and Battese (1992), the latter article giving particular attention to applications in agricultural economics. Beck (1991) and Ley (1990), have compiled extensive bibliographies on empirical applications of frontier functions and efficiency analysis.

However, a few empirical researches have been carried out to estimate the technical efficiency of the tea industries in Bangladesh using stochastic frontier model. Therefore, there is a great need to research the production efficiency of the tea industries, which may contribute largely to the present low performance of the tea industry in Bangladesh. The aim of this study is to estimate the inefficiency of tea industries in Bangladesh and identify the factors causing technical inefficiency of tea industries. In this study, an effort has been made to analyze in measuring technical efficiency of tea industry using the stochastic frontier production function model specified by Battese and Coelli (1995), for the panel data. To determine the sources of inefficiency to improve the existing situations in tea industry are also of our interest.

MATERIALS AND METHODS

In stochastic frontier analysis, the assumption is that the production function of the fully efficient firm is known. Fried, Lovell et al., (1993), have shown that econometric approaches like the stochastic frontier analysis can distinguish the effects of noise from the effects of inefficiency. Since one of the objectives of this research is to examine the production efficiency (scores) of tea industries in Bangladesh, the Stochastic Frontier Analysis was selected as the tool to measure efficiency in this study. We employed a stochastic production frontier approach introduced by Battese and Coelli (1995), and it can be written as

$$Y_{it} = \beta X_{it} + (V_{it} - U_{it}), \quad i = 1,2,\ldots\ldots\ldots \ldots, N; \quad t = 1,2,\ldots\ldots, T \quad \ldots\ldots\ldots\ldots(1)$$

Where Y_{it} the logarithm of output of the ith tea industry is in *t*th period X_{it} is a vector of input quantities;

V_{it}'s random variables which are assumed to be i.i.d., $N(0, \sigma_v^2)$ and independent of U_{it};

U_{it}'s are non-negative random variables which are assumed to account for technical inefficiency in production and to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution; where $U_{it} = Z_{it}\delta$; where; Z_{it} is a $(1 \times p)$ vector of variables which may influence the inefficiency of tea industry and δ is a $(p \times 1)$ vector of parameters to be estimated. The parameterization from Battese and Corra (1977), are used, replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and the parameters are estimated by Maximum Likelihood approach.

The Technical inefficiency effect U_{it} in the stochastic frontier model is specified as follows;

$$U_{it} = Z_{it}\delta + W_{it} \quad \ldots\ldots\ldots\ldots(2),$$

Where, the random variable W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_{it}\delta$. Parameters of the stochastic frontier given by Equation (1) and inefficiency model given by Equation (2) are simultaneously estimated by using maximum likelihood estimation. After obtaining the estimates of U_{it}, the technical efficiency of the I - th tea industry at t - th time period is given by:

$$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) \quad \ldots\ldots\ldots\ldots\ldots\ldots(3).$$

Selecting the functional form of the production function

In order to select the best specification for the production function (Cobb - Douglas or Translog), for the given data set, we conducted hypothesis tests for the parameters of the stochastic frontier production model using the generalized likelihood - Ratio (LR) statistic defined by

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}. \quad \ldots\ldots\ldots\ldots(4)$$

Where $\ln[L(H_0)]$ the value of the log likelihood functions for the stochastic frontier is estimated by pooling the data for all the seven regions under null hypothesis, and $\ln[L(H_1)]$ is the sum of the values of the log - likelihood functions for the seven stochastic production functions (North Sylhet + Juri + Lungla + Manu-Doloi + Balisera + Luskerpore + Chittagong) estimated separately under alternative hypothesis.

Specification of the Stochastic Frontier Translog (Value Added) Model

The functional form of the stochastic frontier Translog production model is defined as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 T + \beta_2 \ln A_{it} + $$
$$+ \beta_{12} \ln A_{it} * T + \beta_{13} \ln L_{it} * T +$$
$$\beta_3 \ln L_{it} + \tfrac{1}{2}\left(\beta_{11} T^2 + \beta_{22} \ln A_{it}^{\ 2} + \beta_{33} \ln L_{it}^{\ 2}\right)$$
$$\cdot \beta_{23} \ln A_{it} * \ln L_{it} + V_{it} - U_{it} \text{.......................(5)},$$

Where, the subscripts i and t represent the i-th tea industry and the t-th year of observation, respectively; $i = 1,2,...,7$; $t = 1,2,...,15$;

Y_{it} denotes the output variables (Value added) of the ith tea industry in the t-th period in values (taka);

T represents time;

A_{it} denotes area of ith tea industry in the t-th period;

L_{it} represents labor of ith tea industry in the t-th period;

"ln" refers to the natural logarithm; the β_i's are unknown parameters to be estimated; V_{it} follows $N(0, \sigma_v^{\ 2})$ and U_{it} follows a truncations at zero of the $N(\mu, \sigma_u^{\ 2})$ distribution and guarantees inefficiency to be positive only.

Identifying sources of technical inefficiency and hypothesis tests

The tea industry specific inefficiency is considered as a function of some explanatory variables and the inefficiency effects model is defined as:

$$U_{it} = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + W_{it} \text{ ....(6)},$$

where δ_0 is the intercept term and δ_j $(j = 1,2,3)$ is the parameter for the j-th explanatory variable and Z_1= Temperature, Z_2= Rainfall, Z_3= Herfindahl-Hirschman index.

The hypothesis tests are obtained using the generalized likelihood-ratio test statistic (4). This test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Taymaz and Saatci, 1997, p. 474).

These are obtained by using the values of the log-likelihood functions for tea industries and the stochastic frontier production function.

Given the specification of the stochastic frontier production function, defined by (5), the null hypothesis that technical inefficiency is not present in these model, is defined by $H_0 : \gamma = 0,$ where γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiency and defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier models by using the computer program FRONTIER version 4.1 developed by Coelli (1996). If the null hypothesis is accepted this would indicate that $\sigma_u^{\ 2}$ is zero, hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square (OLS). Further, the null hypothesis that the technical inefficiency effects are time invariant defined as $H_0 : \eta = 0$. If the null hypothesis is true, the generalized likelihood ratio statistic λ is asymptotically distributed as a chi-square (or mixed chi-square) random variable.

Data description and variable construction

The data were collected from the various issues of Annual Report of *Bangladeshyio Cha Sansad (BCS)* and *International Tea Committee (ITC)* etc. Our study covers total Tea Industry that is available, under registered tea gardens of Bangladesh over the reference period 1990 to 2004.

Value added (Y)

Value added figures are used in this study to represent output and is equal to the value of products and is measured in values (taka). This value added figure is manipulated by the price of yield per hectare and it is treated as gross production or gross output. To obtain the gross output series in constant prices, the yearly current values were deflated by the industry price index of the relevant year. In this analysis gross value added (output) is dependent variable.

Area (A)

Area is one of the essential inputs in measuring productivity. Gross fixed area under tea is used in this study.

Labor (L)

The number of employees directly or indirectly in production is used in this study as a labor input. It covers all workers including administrative, technical, clerical, sales and purchase staff. Thus all production and non-production workers except temporary daily casuals and on paid workers are included in the analysis. In brief, they include production workers, salaried employees, and working proprietors. The best measure of labor input is the number of hours worked. As no such data are available for any industry, employment figures were taken as the second measure and were weighted by the base year wage rate to obtain measure of labor input.

Time (T)

To find the productive efficiency of a i-th tea industry over time we have used time as the input variable. In this study we have used data of 15 years from 1990 to 2004. Explanatory Variables which influence the level of inefficiency is considered also in this study:

Table 1. OLS and MLE estimates of stochastic frontier translog (Value added) model.

Variable	Parameters	Estimated OLS Estimates	Estimated MLE Estimates
Constant	β_0	-17.735 ** (10.448)	- 17.263 * (0.990)
Time	β_1	- 0.023 @ (0.216)	- 0.211 @ (0.170)
Area	β_2	5.983 ** (3.085)	6.141 * (0.748)
Labor	β_3	-1.878 @ (1.881)	- 1.283 * (0.675)
Time * Time	β_{11}	39.987 @ (0.009)	- 92.152 * (55.747)
Area * Area	β_{22}	- 2.161 ** (1.019)	- 2.839 * (0.547)
Labor * Labor	β_{33}	-1.808 ** (0.953)	- 2.257 * (0.568)
Time * area	β_{12}	- 0.079 @ (0.211)	0.098 @ (0.137)
Time * Labor	β_{13}	0.071 @ (0.211)	- 0.070 @ (0.135)
Area * Labor	β_{14}	1.839 ** (0.959)	2.313 * (0.545)
Sigma - squared	σ^2	0.058	
Log likelihood function		**6.001**	**25.203**

N=105 and *, **, *** significance level at 1%, 5%, 10% consecutively, @ means insignificant, and values in the parentheses indicate Standard Error.

Temperature (Z_1)

Temperature is used as influencing variables which are not deflated but actual measurement and its unit of measurement is Fahrenheit.

Rainfall (Z_2)

Rainfall is used as influencing variables which are not deflated but actual measurement and its unit of measurement is millimeter.

Herfindahl - Hirschman Index (Z_3)

The Herfindahl-Hirschman index takes into accounts both the relative size and number of tea industries. Mathematically, HHI is described as follow: $HHI = \sum_{i=1}^{N} S_i^{\,2}$ where N is the number of industries and S_i is share of the i^{th} tea. HHI is known as measure of competition which is measured as the sum of squared of the output share of each tea industry in the output of considered total tea industries in Bangladesh.

RESULTS AND DISCUSSION

Selection of the translog production function

We have tested the hypothesis whether the Translog production function is an adequate representation of the data or not using Equation (5). The values of the log likelihood for the Cobb-Douglas and Translog production frontiers are 18.93 and 25.203, respectively. By employing Equation (4), we have estimated the values of Likelihood Ratio for the Cobb-Douglas and Translog production are 34.267 and 38.389, respectively. These values are compared with the upper five percent points for $\chi^2_{(3,0.05)}$ and $\chi^2_{(9,0.05)}$ which are 3.85 and 10.25, respectively. Finally it is concluded that the null hypothesis $H_0 : \beta_{ij} = 0$ is strongly rejected and it indicates that Translog Production Function is more preferable than Cobb-Douglas Production Function.

Estimating the stochastic frontier translog model

The results of the Ordinary Least Square (OLS) and Maximum-likelihood Estimation (MLE), for the Translog production function as described in Equation (5) are reported in Table 1. From the OLS estimation we have observed that a total of 4 coefficients out of 9 are statistically significant at 5% level, indicating the importance of some of the interactions and non - linearity among variables. The direct effects of area, interaction effects of area and labor, square terms or second order parameters of area and labor are significantly different from zero. These implied that there exists having a major role in tea production. The area remains the single most important input with an output elasticity of 5.983, followed by labor -1.878, respectively. Reasonably enough, for a labor surplus economy, labor has the negative output (value added) elasticity and is found to be insignificant in the production process. This implies that labor does not affect the yield of the tea significantly. The variable time, second order parameter of time, interaction of time and labor and interaction of time and area are found to be insignificant. So we can say that the area and labor with interaction to time do not affect on the value added (production) in tea industries of Bangladesh.

The sign of coefficients of all variables in Equation (5), when estimated with MLE technique are negative but significant except area and its interaction with labor,

Table 2. Region wise mean efficiency of value added for the selected tea regions in Bangladesh.

Year	North Sylhet	Jury alley	Lungla	Manu-doloi	Balisera	Luskerpore	Ctg. Dist.	Mean efficiency
1990	0.38	0.47	0.43	0.61	0.49	0.92	0.34	**0.52**
1991	0.40	0.52	0.41	0.67	0.78	0.72	0.34	**0.55**
1992	0.35	0.48	0.29	0.59	0.70	0.60	0.29	**0.47**
1993	0.32	0.41	0.31	0.55	0.67	0.60	0.30	**0.45**
1994	0.35	0.54	0.36	0.65	0.77	0.68	0.35	**0.53**
1995	0.30	0.48	0.32	0.53	0.60	0.54	0.28	**0.44**
1996	0.37	0.66	0.47	0.74	0.90	0.74	0.42	**0.61**
1997	0.32	0.46	0.31	0.49	0.50	0.52	0.32	**0.42**
1998	0.62	0.90	0.61	0.96	0.95	1.00	0.58	**0.80**
1999	0.38	0.64	0.44	0.70	0.75	0.67	0.42	**0.57**
2000	0.51	0.65	0.49	0.76	0.85	0.63	0.61	**0.64**
2001	0.57	0.72	0.49	0.86	0.82	0.64	0.80	**0.70**
2002	0.50	0.61	0.44	0.79	0.84	0.58	0.58	**0.62**
2003	0.60	0.76	0.52	0.97	1.00	0.70	0.69	**0.75**
2004	0.58	0.72	0.51	0.92	0.95	0.67	0.69	**0.72**
Mean	**0.44**	**0.60**	**0.43**	**0.72**	**0.77**	**0.68**	**0.47**	

interaction in between area and labor which are positive. In this analysis, it is found that the variable time and its interaction with area and labor are insignificant. The direct effects of area, labor, square terms or second order parameters of area and labor and interaction of area and labor are significantly different from zero. This indicates that the rejection of the Cobb-Douglas model as an adequate representation of Bangladesh Tea Industry is justified, because the function is non - linear in some dimensions and there are important interactions among the variables. The variables' area and labor appear to be the major determinants of tea production. However, area remains the single most important input with an output (value added) elasticity of 6.141, followed by labor - 1.283, respectively. Reasonably enough, for a labor surplus economy, labor has the negative output (value added) elasticity and is found to be insignificant at 5% level in the production process. The coefficients of interaction of time with area and labor are 0.098 and - 0.070, respectively indicating that value added (production) is explained only by 9 and 7% by these interaction variables. So from this result we may conclude that the area and labor with time interaction have low output (value added) elasticity. We have observed that the variable area shows significant affect for both OLS and MLE estimation of the Translog stochastic frontier production function. The coefficient on the time trend variable indicates that there is a negative technological progress but it declines downwards with an annual rate of 21.1% per annum and the effect is nonlinear, as indicated by the significant coefficients of the squared terms. Overall these findings support the results of Baten et al. (2009).

Table 2 reveals that the technical efficiency of Bangladesh Tea industry during the period 1990 to 2004 is found to be 0.59 ranging from a minimum of 0.28 to a maximum of 1.00 for value added for the selected tea regions. This implies that 59 percent of potential value added is being realized by the tea industry of Bangladesh. In the present study, none of the estimates had achieved zero level efficiency, while only Balisera in 2003 and Luskerpore in 1998 achieved full level efficiency (100%). The findings also suggest that 41% technical inefficiency exists in the value added of tea. In other words, 59% of the tea estates were able to produce on the production frontier, and 41% were off-frontier of varying degrees for value added. There is wide variation in the technical efficiencies among the different tea producing region. However, the overall value added efficiency for all regions is steadily increasing over time except the year 2004 presented in Figure 1. The highest mean efficiency was in 1998 and it was more than 80% which is 50% higher than previous year. The average efficiency in 2004 was 4% lower than 2003. We observed that the value added efficiency in tea producing regions (like north Sylhet, Jury and Ctg.) in Bangladesh during the period 1990 - 2004 have lower efficiency comparable to other regions. The year wise value added average productive efficiency has been illustrated also by Figure 2 separately. Year wise value added (productive) efficiency seems to be unstable during the study period. The efficiency for value added was least for the year 1997 but its highest efficiency for the year 1998. It is hope that there has been a general improvement occurred after the year 1997.

Following the Figure 3, we have also observed that Balisera and Manu - Doloi are most efficient in producing tea with 77 and 72% respectively. This result indicates that big size (measuring their total area, technology) regions are comparatively more efficient. The lowest efficiency is in the Lungla (42%). From the analysis we

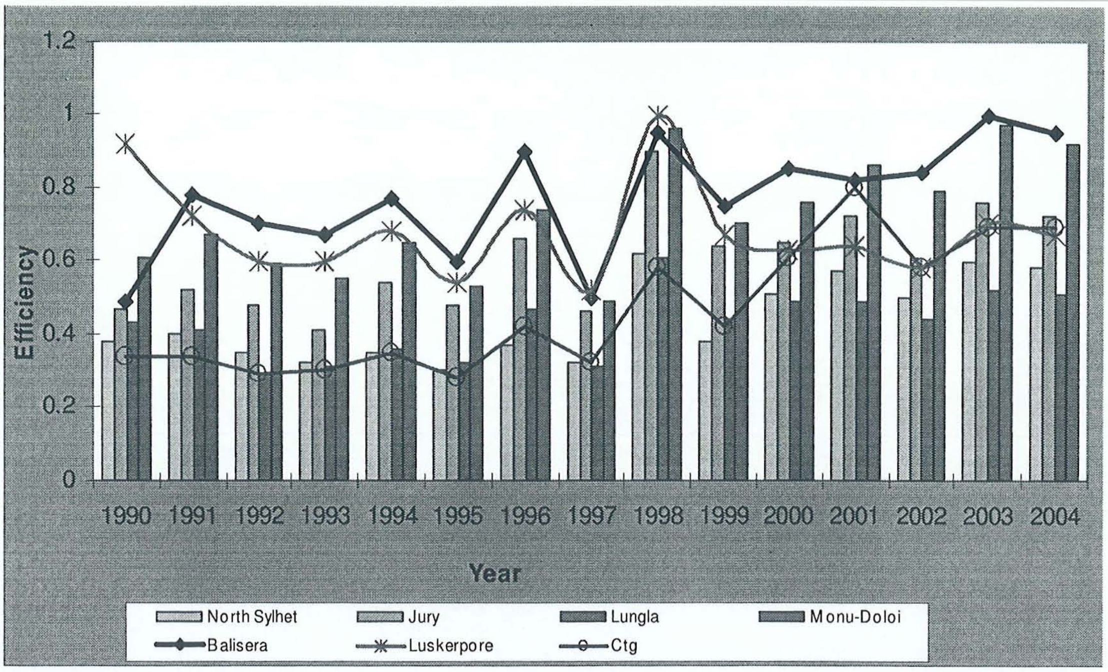

Figure 1. Value added efficiency in tea producing regions in Bangladesh, 1990 - 2004.

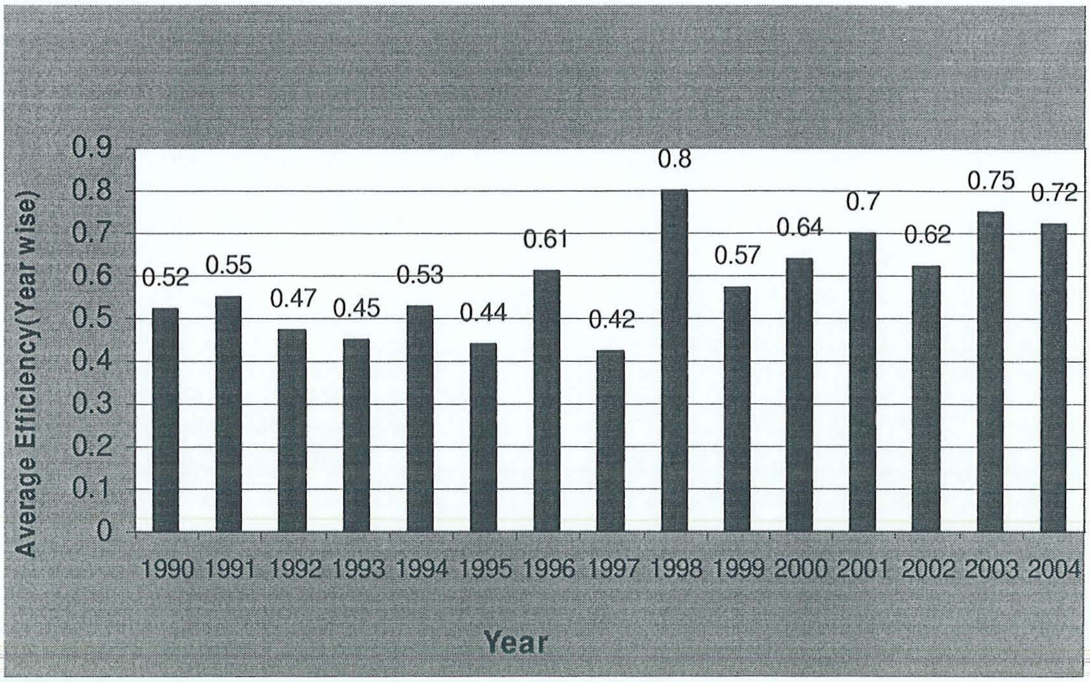

Figure 2. Year-wise value added average efficiency in tea industries of Bangladesh, 1990 - 2004.

observed that the Lungla valley and North Sylhet are so far lowered efficient in producing tea comparing to other regions. May be these less efficient regions are concentrating in other services rather than value added.

Estimating the inefficiency effect model

In order to investigate the determinants of inefficiency, we have estimated the technical inefficiency model described

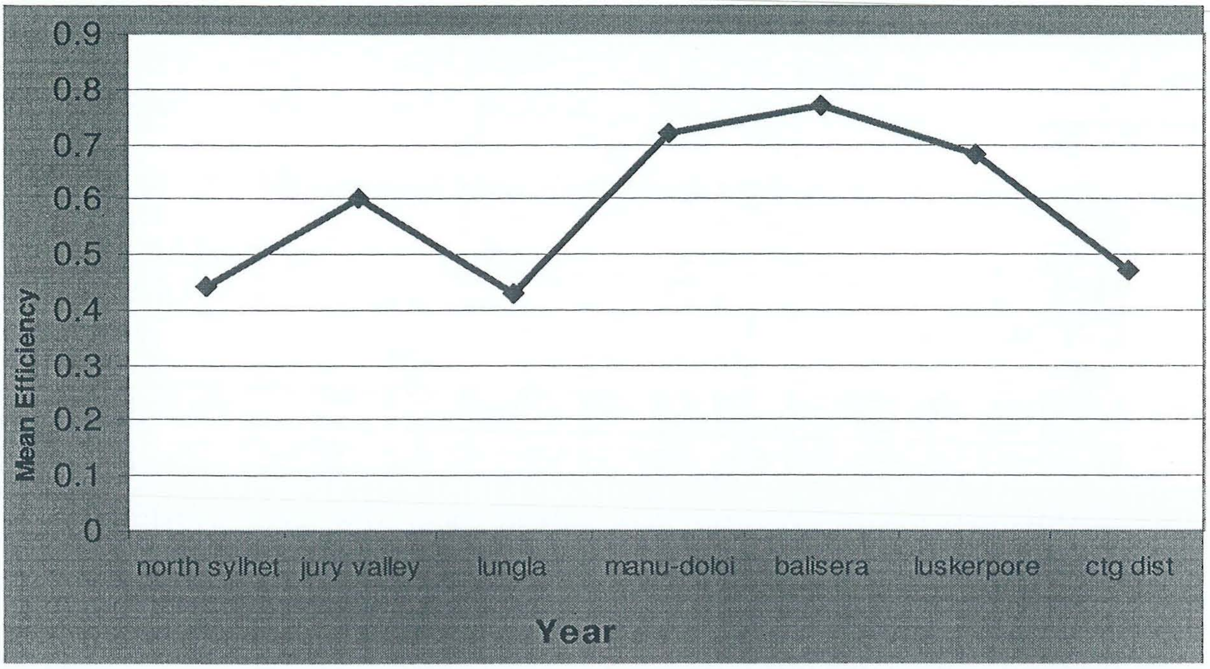

Figure 3. Region - wise value added average efficiency in tea industries of Bangladesh, 1990 - 2004.

Table 3. Inefficiency effects model for value added.

Variable	Parameters	MLE Coefficients
Constant	δ_0	4.677* (0.959)
Temperature	δ_1	0.500** (0.285)
Rainfall	δ_2	0.077@ (0.088)
HHI	δ_3	-1.088* (0.155)
sigma-squared	σ^2	0.041* (0.008)
gamma	γ	0.999* (0.00001)

*, **, *** indicate significance level at 1,5 and10% consecutively, values in the parentheses indicate S.E. and @ indicates Insignificance.

in Equation (6) presented in Table 3. The sign of coefficients of the variable HHI is negative but significant impact on tea production. These indicate that HHI variable is inversely related with inefficiency. The variable temperaturé significantly contributes to improved technical efficiency in tea production and this implies that temperature should be one of the major variables in order to improve technical efficiency in tea production. The sign of the coefficient of rainfall indicates that rainfall is less efficient although the coefficient is not statistically significant. Using the composed error terms of the stochastic frontier model, it is defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ which is a measure of level of the inefficiency in the variance parameter and it ranges between 0 and 1. It is observed that the MLE estimate of γ is 0.999 with estimated standard error of 0.00001. The value of γ is significantly different from one indicating that random shocks are playing a significant role in explaining the variation in tea production, which is expected in tea production where uncertainty is assumed to be the main source of variation. This implies that the stochastic production frontier is significantly different from the deterministic frontier, which does not include a random error. This indicates that the random component of the inefficiency effects does make a significant contribution in the analysis. In the MLE estimation, γ is positive and significant at 1% level, implying that tea industry specific technical efficiency is important in explaining the total variability of value added produced. However, it should be noted that 99 percent of the variation in production is due to technical inefficiency and only 1 percent is due to the stochastic random error.

Results of hypothesis tests

The results of various hypotheses tests for the specification model (5) are presented in Table 4. The value of log likelihood function for OLS and MLE allow to test whether technical inefficiency exists or not. In case technical inefficiency does not exist then technically, there will be no difference in the parameters of OLS and MLE. The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution, because the restriction defines a point on the boundary of parameter space γ. The first null hypothesis $H_0 : \gamma = 0$ for the

Table 4. Likelihood-Ratio Test of Hypothesis of the Stochastic Frontier Translog Model.

Null Hypothesis	Log-likelihood Function	Test Statistic λ	Critical Value*	Decision
$H_0 : \gamma = 0$	6.0085	38.389	10.25	Reject H_0
$H_0 : \beta_{ij} = 0$	1.8002	34.267	3.85	Reject H_0
$H_0 : \eta = 0$	6.019	40.419	5.21	Reject H_0

Notes: All critical values are at 5% level of significance.
*The critical values are obtained from table of Kodde and Palm (1986).

Value added specification model which specify that there is no technical inefficiency effects in the model. The value of the logarithm of the likelihood function provides generalized likelihood ratio test statistic of 38.389, which is larger than the critical value of 10.25. So the hypothesis is rejected and we can conclude that there is a technical inefficiency effect, given the specifications of the stochastic frontier and inefficiency effect model. Hence the stochastic frontier model does appear to be a significant improvement over an average production function that supports the results of Basnayake and Gunaratne (2002). The second null hypothesis $H_0 : \beta_{ij} = 0$ indicates that Cobb-Douglas Production Function is more preferable than Translog Production Function. From the outcome, it is observed that the null hypothesis is strongly rejected and Translog Production Function is statistically more favorable. The third null hypothesis is $H_0 : \eta = 0$, which specifies that the technical inefficiency effect does not vary significantly over time. The null hypothesis is rejected indicating that the technical inefficiency effect varies significantly.

There are not many studies carried out to estimate production efficiency using tea industries data in Bangladesh. Recently, Baten et. al., (2009) used panel data to estimate the production frontier and the technical inefficiency effects of tea production using a Stochastic Frontier Analysis (SFA) methodology. Their studies fail to consider value added (output variable) for the measurement of tea productive efficiency. Our results are mostly compatible in measuring industries or firm's performance to some international studies such as Fahr and Sunde (2005) and Schettini et. al. (2008). It was found that the technical efficiency estimates are highly sensitive to the functional form specified because the Translog model yielded different technical efficiencies. However, the Translog specification is used in the interpretation as it is accepted by the data. The second stage analysis, which identifies the determinants of the inefficiency, should be done for a meaningful policy implication. Labors are found to be more inefficient even when they are expected to be major determinants of tea production industry. This may be because their lacking of knowledge and information provided them the extension officers. Therefore it is necessary to increase educational facilities in the area. This study, however, emphasize the potential improvement of Bangladesh tea industry through industry efficiency improvement, which can allow Bangladesh to regain the competitiveness in the world tea market.

Concluding remarks

This study focused on the estimation of the technical efficiency of the tea producing industries in Bangladesh, applying the Stochastic Frontier Approach and to identify the factors causing inefficiency over the reference period 1990 to 2004. The rejection of the Cobb-Douglas model as an adequate representation of Bangladesh Tea Industry was justified, because the function is non-linear in some dimensions and there are important interactions among the variables. The variables, both area and labor, disappeared to be the major determinants on the tea industry production. According to the results obtained from the stochastic frontier estimation, the average technical efficiency of tea industry given by the Translog model is 59%. This indicates that there is a scope to further increase the output by 41% without increasing the levels of inputs.

From the inefficiency effects model, we have found that the variable HHI shows negative but impact on tea production and temperature, significantly contributed to improve technical efficiency in tea production. We concluded that temperature was one of the major variables in order to improve technical efficiency in tea production in Bangladesh, but it is surprising about rainfall which was found less efficient although, it is not statistically significant. For the MLE, γ is estimated at 0.99, this can be interpreted that 99% of random variation is the Value added among the tea industry production due to inefficiency.

ACKNOWLEDGEMENT

The authors wish to acknowledge the support provided by Research University Grant, No. 1001/PJJAUH/ 811130, University Sains Malaysia, Penang, Malaysia for conducting this research.

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African Journal of Business Management Vol. 4(12), pp. 2438-2449, 18 September, 2010
Available online at http://www.academicjournals.org/AJBM
ISSN 1993-8233 ©2010 Academic Journals

Full Length Research Paper

A stochastic frontier model on measuring online bank deposits efficiency

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Accepted 8 June, 2010

An attempt has been made to investigate the online bank specific deposits efficiency using stochastic frontier technique and it intends to determine various factors affecting the efficiency level of banks for the period 2001 - 2007. We used a panel of 20 banks divided into four groups namely, NBs (National Banks), ISBs (Islamic Banks), FBs (Foreign Banks), and PBs (Private Banks) in Bangladesh. In this study, a comparison was made with the efficiency scores of banks group-wise, year-wise and individually. This study showed that the estimated year-wise average online banks deposits efficiency was 0.738 while group-wise average deposits efficiency was 0.777. At the bank group level, Nationalized Commercial Banks (NBs) and Islamic Banks (ISBS) were more efficient by 90.9 and 86.8% respectively, followed by Private Banks (PBs) which had 63.4% and Foreign Banks (FBs), 62.7%. We observed that the foreign banks were less efficient in producing deposits. However, the overall deposits efficiency of all bank groups steadily increased over time except in 2007. The most efficient bank was found to be Islami Bank Ltd. and the most inefficient bank was Pubali Bank with efficiency scores of 0.96 and 0.52, respectively.

Key words: Deposits efficiency, stochastic frontier analysis, banking industry.

INTRODUCTION

Banking efficiency has long been a subject of many studies and most of the studies have focused on industrial countries like US and Europe. Research on developing countries is a recent phenomenon. Commercial banks, which are the main component of the banking system, have to be efficient; otherwise they will create maladjustments and impediments in the process of development in any economy. Efficiency measurement has been of concern to researchers with an aim to look into the efficiency levels of different commercial banks engaged in various production activities. Identifying determinants of efficiency levels is a major concern in efficiency analysis. The studies of efficiency using stochastic frontier approaches on banking did not start until Sherman and Gold (1985) initiated their own. They applied the frontier approach to the banking industry by focusing on the operating efficiency of the branches of a savings bank. Since then, numerous studies have been conducted using frontier approaches to measure banking efficiency. There have been extensive studies on bank efficiency done in the US and European countries on conventional banking (Berger and Humphrey, 1997; Goddard et al., 2001). No attempt has been made to check the performance and efficiency measure of the commercial banks with loan default; however, some work has been done for Bangladesh banking sector (Raihan, 1998; Choudhury et al., 2000; Choudhury, 2002; Dilruba and Khandoker, 2005). Bangladesh banking industry is an interesting topic for our study for two reasons. First, no earlier studies have been intended to estimate the bank deposits efficiency in Bangladesh. Second, Bangladesh banking sector is one of the most booming industries in this sub-continent, and foreign investors are increasingly trying to grasp this healthy sector.

Past studies on bank efficiency and other financial institutions have focused mainly on the USA (Aly et al., 1990; Elyasiani and Mehdian, 1990; Kwan and Eisenbeis, 1996) and other developed countries (Worthington, 1998), for example Australian (Koetter, 2005) and German banking. In countries like Australia (Sturn and Williams, 2004), Spain (Lozano-Vivas, 1997), Turkey (Isik

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and Hasan, 2003) and Norway (Berger et al., 1992) financial liberalization has positively affected the efficiency and productivity of commercial banks; for Italy (Boscia, 1999), US (Bauer et al., 1993) and other banking efficiency was relatively unchanged after regulation. Surprisingly, in Korea, productivity of the banking sector has declined after deregulation (Mahadevan, 2004). Banks have been faced with growing competition, both from themselves and from firms and markets outside the industry (Wheelock, 1993) and presumably banks will be more successful in maintaining their business if they operate efficiently. Berger and Humphrey (1992) found that during the 1980s high-cost banks experienced higher rates of failure than more efficient banks. Similarly, in a study of bank failures during the 1920s, Wheelock and Wilson (1995) found that the less technically efficient a bank was, the greater its likelihood of failure. There has been a widespread discussion on lack of adequate technical efficiency of banks in developing countries (Das, 1997; Shanmugan and Lakshmanasamy, 2001; Kumar and Verma, 2003; Mohan and Ray, 2004; Das et. al., 2005; Kumbhakara and Sarkar, 2003; De, 2004; Sensarma, 2005; Mahesh et al., 2006).

This type of investigation into bank efficiency is quite important from the viewpoint of macroeconomics as well, since the adequate development of financial markets is essential for stabilizing the macro-economy and accelerating economic growth. In addition, efficiency measure of commercial banks is important for at least two reasons. First, efficiency measures are indicators of success, by which the performance of individual banks, and the industry as a whole, can be gauged. The second reason to investigate the efficiency of commercial banks is the potential impact of government policies on efficiency. Therefore this study intends to reveal the overall performance of commercial banks with loan default and measuring bank deposits efficiency in Bangladesh. In an economy where resources are scarce and opportunities for new technologies are lacking in efficiency, studies will be able to raise productivity by improving efficiency without the resource base or developing new technology. Therefore, it is essential to determine the status of productivity growth which is being decomposed with efficiency and technical change. This is because determining the efficiency status of Bangladesh banks is very important for policy purpose. To the researchers' best knowledge, this is the first time the stochastic frontier approach is being used to analyze the bank deposits efficiency in Bangladesh.

Previous research that has focused on developing countries like Bangladesh is still considered small. This motivates us to undertake this study to fill the gap and add to the existing literature. As a means of addressing this issue within a unified and consistent framework, we propose a variant of the increasingly popular Battese and Coelli (1995) model to examine the bank deposits efficiency level in Bangladesh. The main focus of our study is to measure the bank deposits technical efficiency in accordance with four groups namely NBs (Nationalized Commercial Banks), IBs (Islamic Banks), and PBs (Private Banks) of Bangladesh. The considered model is also used to determine the important factors causing efficiency differential on Bangladesh banking industry.

Given this background, the paper is organized as follows: in the next section we discuss briefly the Bangladesh banking system. Third section contains discussion about the methodology used for measuring deposits efficiency; and various approaches of deposits (output) measurement in the banking sector and details about the data used for this study are presented; and the estimated results are presented in the penultimate section. The concluding section sums up the findings.

Bangladesh banking industry and its importance

The banking industries are the leaders of the financial-services industry. They are the place where we often wind up when we are seeking a loan to purchase a new automobile, tuition for college or a professional school, financial advice on how to invest our savings, credit to begin a new business, a safe deposit box to protect our most valuable documents, a checking account to pay for purchases of goods and services, or a credit or debit card so we can conveniently keep track of when and where we spend our money. Financial firms other than banks are selling us these same services, but banks still head the list of financial service providers in many markets. The banking industries dominate Bangladesh's financial sector. Bangladesh bank is the Central Bank of Bangladesh and the chief regulatory authority in this financial sector. The banking system consists of four nationalized commercial banks, about forty private commercial banks, nine foreign multinational banks and some specialized banks. The Nobel-prize winning Grameen Bank is a specialized micro-finance institution, which revolutionized the concept of micro-credit and contributed greatly towards poverty reduction and the empowerment of women in Bangladesh. The banking industry of Bangladesh is a mixed one comprising nationalized, private and foreign commercial banks. These banks are the main vehicles for mobilizing invisible funds and channeling those funds to fasten the growth of the productive sectors of the economy. Banks in Bangladesh have been operating under both public and private sectors for about two decades. The question arises on how successfully the nationalized private commercial banks are serving the country, and how far they have achieved their desired goals. It is commonly believed that the nationalized commercial banks overcome the vicious problem of corruption, inefficiency, loan default etc. although the private commercial banks are efficient in their commercial activities and solving the problem of loan default.

The banking system of Bangladesh is dominated by the 4 nationalized commercial banks, which together controlled more than 54% of deposits and operated 3388 branches (54% of the total) as of December 31, 2004. Private banks belong to the highest growth sector due to the dismal performances of national/government banks. Foreign banks are also among the growth sector due to the performances of national commercial banks. They tend to offer services by providing disbursed loan and defaulted loan as well as playing a pioneer role in introducing modern financial products and services. Out of the specialized banks, two (Bangladesh Krishi Bank and Rajshahi Krishi Unnayan Bank) were created to meet the credit needs of the agricultural sector while the other two (Bangladesh Shilpa Bank (BSB) and Bangladesh Shilpa Rin Sangtha (BSRS)) are for extending term loans to the industrial sector. The Bangladesh banking sector relative to the size of its economy is comparatively larger than many economies of similar level of development and per capita income. The total size of the sector at 26.54% of GDP dominates the financial system, which is proportionately large for a country with a per capita income of only about US$540. The non-banking financial sector, including capital market institutions is only 3.22% of GDP, which is much smaller than the banking sector. Access to banking services for the population has improved during the last three decades. While population per branch was 57,700 in 1972, it was 19,800 in 1991. In 2001 it again rose to 21,300, due to winding up of a number of branches and growth in population. Compared to India's 15,000 persons per branch in 2000, this indicates that the banking system in Bangladesh is a significant problem. The list of online banks considered in this study with serial number is presented in Table 1.

METHODOLOGY

A theoretical stochastic frontier model

Technical efficiency measurement by frontier method is based on the assumption that a gap normally exists between a firm's actual and potential levels of technical performance. Thus the technical efficiency is measured as the ratio between actual output and the potential output. While there are various methods of measuring technical efficiency (see Lovell 1993, Coelli et al., 1998, and Kumbhakar and Lovell 2000), in the present study we use the approach proposed by Battese and Coellli (1995) which explicitly accounts for statistical noise. The specification of the model may be expressed as:

$$Y_{it} = \beta X_{it} + (V_{it} - U_{it}),\ i = 1,2,........,N;\quad t = 1,2,.......,T \quad ....(1)$$

where Y_{it} is the logarithm of output of the i^{th} bank in t^{th} period; X_{it} is a vector of input quantities; β_i's are unknown parameters to be estimated; V_{it}'s random variables which are assumed to be i.i.d., $N(0,\sigma_v^2)$ and independent of U_{it}; U_{it}'s are non-negative non-negative random variables which are assumed to account for technical inefficiency in output and to be independently distributed as truncations at zero of the $N(\mu,\sigma_u^2)$ distribution; where $U_{it} = Z_{it}\delta$; Z_{it} is a $(1\times p)$ vector of variables which may influence the inefficiency of bank industry and δ is a $(p\times 1)$ vector of parameters to be estimated. The parameterization from Battese and Corra (1977) are used replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$.

The technical inefficiency effect U_{it} in the stochastic frontier model is specified as follows:

$$U_{it} = Z_{it}\delta + W_{it} \quad ....\ .(2),$$

where the random variable, W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_{it}\delta$. Parameters of the stochastic frontier given by equation (1) and inefficiency model given by equation (2) are simultaneously estimated by using maximum likelihood estimation (Battese and Coelli, 1993). After obtaining the estimates of U_{it} the technical efficiency of the i-th bank industry at t-th time period is given by:

$$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) \quad ....(3).$$

A stochastic frontier model for deposits (in) efficiency

The functional form of the deposit translog stochastic frontier production model is defined as:

$$\begin{aligned}\ln(Y_{it}) =& \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln M_{it} + \beta_3 \ln L_{it} + \beta_4 T \\ &+ \tfrac{1}{2}\left(\beta_{11}\ln K_{it}^2 + \beta_{22}\ln M_{it}^2 + \beta_{33}\ln L_{it}^2 + \beta_{44}T^2\right) \\ &+ \beta_{12}\ln K_{it} * \ln M_{it} + \beta_{13}\ln K_{it} * \ln L_{it} + \beta_{14}\ln K_{it} * T + \beta_{23}\ln M_{it} * \ln L_{it} \\ &+ \beta_{24}\ln M_{it} * T + \beta_{34}\ln L_{it} * T + V_{it} - U_{it} ....(4),\end{aligned}$$

where, the subscripts i and t represent the i-th bank industry and the t-th year of observation, respectively; $i = 1, 2,...,20$; $t = 1, 2,...,7$; Y_{it} denotes the output variables (deposits) of the ith bank industry in the t-th period in values (taka); K_{it} denotes capital (fixed assets of a bank in a year which also adds premises, furniture and fixture) of i-th bank industry in the t-th period; M_{it} represents materials (the sum of expenditure on printing and stationeries and postage, telegrams and telephones etc) of i-th bank industry in the t-th period; L_{it} represents labor (the total number of employees which include officers, sub-ordinates and clerks) of i-th bank industry in the t-th period; T represents year of observation; "ln" refers to the natural logarithm.

Identifying sources of technical inefficiency effects and hypothesis tests

The bank industry specific inefficiency is considered as a function of some explanatory variables and the inefficiency effects model is defined as:

$$U_{it} = \delta_0 + \delta_1 T + \delta_2 TA + \delta_3 HI + \delta_4 NB + \delta_5 ISB + \delta_6 FB + \delta_7 PB + W_{it} .....(5),$$

where δ_0 is the intercept term and δ_j $(j = 1, 2, 3, 4, 5, 6, 7)$ is the parameter for the j-th explanatory variable, T=Year of observation, TA=Total Assets, HI=Herfindahl Index, NB is the dummy variable for Nationalized Commercial Banks: NB=1 if an observation involves a Nationalized Commercial Bank, zero otherwise; ISB is the dummy variable for Islamic banks: ISB=1 if an observation involves an Islamic bank, zero otherwise; FB is dummy variable for Foreign Banks: FB=1 if an observation involves a Foreign Bank, zero otherwise; PB is dummy variable for Private Banks: PB=1 if an observation involves a Private Bank, zero otherwise.

Likelihood ratio tests and hypothesis

The following hypotheses that require testing with the generalized likelihood ratio test statistic are defined by

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \cdots (6)$$

where $L(H_0)$ and $L(H_1)$ are the value of the likelihood function for the deposits frontier model under the null and alternative hypotheses. Under the null hypothesis, this test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Taymaz and Saatci 1997). These are obtained by using the values of the log–likelihood functions for the banking industries and the stochastic frontier production function.

The following null hypotheses will be tested:

$H_0 : \beta_{ij} = 0,$ the null hypothesis that identifies an appropriate functional form either the restrictive Cobb-Douglas or Translog production function. It specifies that the second-order coefficients of the stochastic frontier production function are simultaneously zero.

$H_0 : \gamma = 0,$ the null hypothesis specifies that the technical inefficiency effects in banks are zero. This is rejected in favor of the presence of inefficiency effects. Here γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiency and defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier models by using the computer program frontier version 4.1 developed by Coelli (1996). If the null hypothesis is accepted this would indicate that σ_u^2 is zero and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square (OLS).

Further $H_0 : \eta = 0,$ the null hypothesis that the technical inefficiency effects are time invariant that is, there is no change in the technical inefficiency effects over time. If the null hypothesis is true, the generalized likelihood ratio statistic λ is asymptotically distributed as a chi-square (or mixed chi-square) random variable.

Measurement of variables

One of the crucial debated issues in the banking literature is output measurement. Though there are a number of alternative approaches of measuring output, they can be grouped into two broad categories (a) Production approach and (b) Intermediation approach. Under this approach output is measured by the number and type of transactions or accounts (both deposit and loan) and inputs used are only physical units such as labour and capital, since, only physical inputs are needed to provide financial services. Under intermediation approach, financial institutions are thought of as primarily intermediating funds between savers and investors. Under this approach, the inputs of the bank are essentially financial capital, and outputs are measured by the volume of loans and investments outstanding. The present study adopts production approach to specify outputs and inputs of commercial banks. Accordingly, deposits are defined as the outputs of commercial banks which are produced by using inputs like labour, capital and materials. All nominal values are converted to real by deflating with GDP deflator and all values are in their natural logarithms.

Data set

We have used data for the period of 2001-2007 from 20 commercial banks of Bangladesh. Banks are grouped into four categories (i) National Banks (NBs), (ii) Islamic Banks (ISBs), (iii) Foreign Banks (FBs), (iv) Private Banks (PBs). Most of the data are collected from the annual reports of the specific banks of Bangladesh and rest of them are collected from annual accounts of Scheduled Commercial Banks published by Bangladesh Bank, the Central Bank of Bangladesh. Deposits are measured as total deposits. Capital is measured as fixed assets (which includes premises, furniture and other fixed assets). Number of employees is measured as the total number of employees. Material is measured as the sum of expenditure on printing and stationeries, postage, telegrams and telephone etc. All nominal values are converted on real by deflating with GDP deflator and all values are in their natural logarithms.

Dependent variables

Deposit (Y)

A bank acquires funds by issuing (selling) liabilities, which are consequently referred to as sources of funds and deposit is one of the significant sources to increase funds. In this study deposit figures are used to represent the dependent variable and equal to total deposits including checkable, non transaction deposit such as savings accounts, time deposits etc. These figures are then deflated by the relevant consumer price index.

Independent variables

Capital (X_1)

Capital is the input variable representing the fixed assets of a bank in a year which also adds premises, furniture and fixture. Capital figures are deflated by capital price index.

Labour (X_2)

Labour is one of the most important inputs to measure the productivity of a firm. Here labour means number of employee and is measured as the total number of employees which includes officers, sub-ordinates and clerks.

Material (X_3)

For the banking sector, materials have been used as the sum of expenditure on printing and stationeries and postage, telegrams and telephones etc. Material prices are deflated by non-food price index.

Time (X_4)

To find the productive efficiency of a bank over time we have used time as the input variable. In this study we have collected data of seven years from 2001 to 2007 and used 1 for year 2001, 2 for 2002 and so on.

Explanatory variables

Time (Z_1)

Time is also used in this study as influencing variable.

Total asset (Z_2)

Total asset is used as the influencing variable and is the sum of all assets and their book value.

Herfindahl index (Z_3)

The Herfindahl-Hirschman index takes into accounts both the relative size and number of banks in the banking sector. Mathematically, HHI is described as follows: $HHI = \sum_{i=1}^{N} S_i^2$ where N is the number of banks and S_i is share of the i^{th} bank. HHI is known as measure of competition which is measured as the sum of squared of the output share of each bank in the output of considered total banks in Bangladesh.

NB, ISB, FB, and PB are bank group specific dummies for National, Islamic, Foreign and Private Banks, respectively. The dummy variables can take either 1 or 0 depending on whether data are available or not.

RESULTS AND DISCUSSION

In this section, the bank deposits efficiency estimates were measured using a stochastic Translog Production Frontier model proposed by Battese and Coelli (1995) applied to panel data. The parameters of Ordinary Least Square Estimates (OLS) and Maximum Likelihood Estimates (MLE) were reported on measuring bank deposits efficiency in Bangladesh. A two step process was used to find out the technical efficiency using maximum likelihood method. In the first step using frontier 4.1 by grid search the ordinary least square estimates of parameters were obtained and these estimates were used to estimate the maximum likelihood estimates of the parameters using the Translog Frontier Production function. This section was devoted to examine the overall performance of banks in Bangladesh.

Results of stochastic frontier model for deposits inefficiency

Bank deposits efficiency over time was estimated as the ratio between actual deposits and the maximum possible deposits. The ordinary least square estimates of the parameters which showed the average performance of the sample banks were presented in Table 2. From the analysis we observed that all the coefficients, except the interaction between capital and labor, squared of time are statistically significant in the deposit production process. The maximum likelihood estimates of parameters of deposits Translog stochastic frontier production model are presented in Table 3. From the maximum likelihood estimates of the deposits model we observed that the coefficients of capital, the squared of time, the interaction between capital and material, and the interaction between capital and time are insignificant. The coefficient of capital is 0.050 which indicated that bank deposits (output) are explained only by 5% capital. So from this result we concluded that the capital has low output elasticity. The coefficient of material input variable showed a negative sign, indicating that banks which use less material (Stationary, postage, and other materials) are more productive. The linear inefficiency model consisted of eight explanatory variables. The coefficients of HHI, NB, ISB, and PB dummies were found interestingly insignificant. The important variable which has significant impact an efficiency measure is the 'Competition', which was measured by HHI. Its positive sign showed that efficiency increases when competition increases. Though the coefficients of dummies were observed insignificant in efficiency measures except Foreign Bank (FB) dummy, their signs differ across different services. In deposits inefficiency model we observed that the coefficient of total assets contains negative sign which indicated that the more the total asset the more the bank efficient. From the coefficient of FB dummies it appeared to be the same and it showed positive sign. This suggested that the foreign banks were not in the race to increase their deposits level which we easily understood from the coefficient of HHI that was found to be statistically insignificant.

The year-wise average bank deposits efficiency is illustrated in Table 4 and Figure 1. The average deposit efficiency estimates for the total banking industry (for the entire study period) are 0.738, which suggested that on an average, banks were 73.8% efficient in producing deposit

Table 1. List of online banks considered in this study.

List of online bank's name	Serial number
Sonali Bank	1
Janata Bank	2
Islami Bank	3
Shahajal Islami Bank	4
Al Arafah Bank	5
Bank Asia	6
The City Bank	7
National Bank	8
Prime Bank	9
Uttara Bank	10
One Bank	11
UCB Bank	12
Pubali Bank	13
Priemer Bank	14
Mutual Bank	15
South East Bank	16
Eastern Bank	17
AB Bank	18
Dhaka Bank	19
DBBI	20

Table 2. OLS estimates of translog stochastic frontier production function: Deposits frontier estimates.

Variable	Parameter	Coefficient	S.E	t-value
Constant	β_0	9.829*	0.736	13.358
Capital	β_1	-0.461**	0.268	-1.720
Material	β_2	0.923*	0.380	2.432
Labour	β_3	-0.960*	0.203	-4.733
Time	β_4	0.349*	0.078	4.486
Capital*Capital	β_{11}	0.218*	0.092	2.361
Material*Material	β_{22}	-0.432*	0.154	-2.804
Labour*Labour	β_{33}	0.059*	0.022	2.739
Time*Time	β_{44}	-0.012@	0.010	-1.201
Capital*Material	β_{12}	-0.144***	0.092	-1.566
Capital*Labour	β_{13}	-0.011@	0.047	-0.235
Capital*Time	β_{14}	-0.235***	0.019	-1.293
Material*Labour	β_{23}	0.269*	0.065	4.150
Material*Time	β_{24}	0.036***	0.028	1.292
Labour*Time	β_{34}	-0.028**	0.013	-2.200
Sigma-squared		0.048		
Log likelihood function		21.949		

*, **, *** Significance level at 1, 5 and 10% consecutively; @ means insignificant S.E = standard error.

Table 3. Maximum-likelihood estimates of bank deposits Translog Stochastic Frontier Production Function and Inefficiency Effects model.

Maximum-likelihood estimates				
Variable	**Parameter**	**Coefficient**	**S.E**	**t-value**
Constant	β_0	8.525*	0.676	12.615
Capital	β_1	0.050@	0.200	0.249
Labour	β_2	1.851*	0.244	7.588
Material	β_3	-1.266*	0.210	-6.023
Time	β_4	0.161**	0.094	1.708
Capital*Capital	β_{11}	0.072***	0.055	1.326
Labour*Labour	β_{22}	-0.757*	0.134	-5.643
Material*Material	β_{33}	0.056*	0.014	3.944
Time*Time	β_{44}	-0.010@	0.011	-0.921
Capital*Labour	β_{12}	-0.158**	0.077	-2.047
Capital*Material	β_{13}	0.033@	0.028	1.187
Capital*Time	β_{14}	0.007@	0.009	0.774
Labour*Material	β_{23}	0.295*	0.049	6.005
Labour*Time	β_{24}	0.077*	0.023	3.299
Material*Time	β_{34}	-0.048*	0.008	-5.476
Inefficiency model estimates				
Constant	δ_0	0.727@	0.784	0.928
Time	δ_1	0.062*	0.027	2.333
Total assets	δ_2	-0.120**	0.072	-1.664
Herfindahl index	δ_3	0.005@	0.047	0.107
NB dummy	δ_4	-0.363@	0.603	-0.602
ISB dummy	δ_6	-0.066@	0.486	-0.135
FB dummy	δ_7	0.643***	0.495	1.299
PB dummy	δ_8	0.512@	0.473	1.083
Sigma-squared (σ^2)		0.073*	0.014	5.070
Gamma (γ)		0.999*	0.000003	3.111

*, **, *** Significance level at 1, 5 and 10% consecutively; @ means insignificant, S.E = standard error.

Table 4. Year-wise average deposits efficiency of banks in Bangladesh.

Year	Mean
2001	0.765
2002	0.793
2003	0.736
2004	0.766
2005	0.702
2006	0.731
2007	0.675
Mean	0.738

services compared to the best practicing bank operating in the same environment. The highest deposits efficiency was in 2002 and it was near to 80% which was 3.66% higher than previous year. The average deposits efficiency in 2007 was 67.5% which was 7.66% lower than 2006. Year wise average deposits efficiency seemed to be unstable during the study period.

As shown in Table 5 and Figure 2, while the deposits efficiency of Nationalized Commercial Banks (NBs) and Islamic Banks (ISBs) increased over the time period, for

Table 5. Year-wise bank group level efficiency in deposits.

Year	NB	ISB	FB	PB
2001	0.892	0.919	0.562	0.741
2002	0.976	0.890	0.671	0.761
2003	0.830	0.882	0.722	0.690
2004	0.857	0.851	0.690	0.745
2005	0.863	0.853	0.669	0.647
2006	0.960	0.906	0.606	0.675
2007	0.988	0.776	0.518	0.627
Mean	0.909	0.868	0.634	0.698

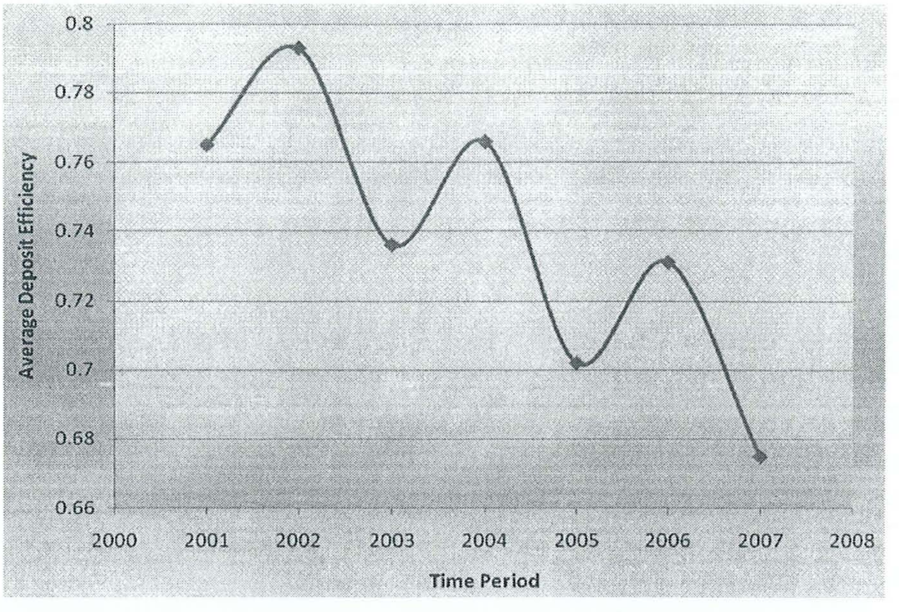

Figure 1. Year-wise average bank deposits efficiency in Bangladesh.

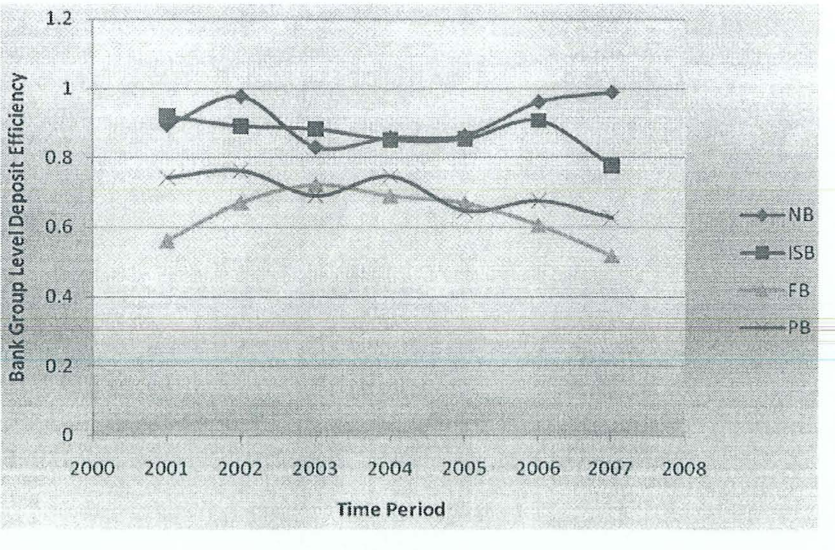

Figure 2. Bank group level average deposits efficiency in Bangladesh.

Table 6. Deposits efficiency of banks in Bangladesh.

Bank's name	2001	2002	2003	2004	2005	2006	2007	Mean efficiency
Sonali Bank	0.96	0.99	0.86	0.90	0.95	0.92	0.99	0.94
Janata Bank	0.82	0.96	0.80	0.81	0.77	1.00	0.99	0.88
Islami Bank	0.93	0.99	0.95	0.97	0.96	0.92	1.00	0.96
Shahajal Islami Bank	0.93	0.97	0.86	0.74	0.82	0.92	0.71	0.85
Al Arafah Bank	0.90	0.71	0.83	0.84	0.78	0.88	0.62	0.79
Bank Asia	0.49	0.72	0.85	0.81	0.68	0.64	0.57	0.68
The City Bank	0.63	0.62	0.59	0.57	0.65	0.57	0.46	0.59
National Bank	0.76	0.69	0.59	0.54	0.48	0.49	0.49	0.58
Prime Bank	0.80	0.77	0.75	0.80	0.71	0.92	0.95	0.81
Uttara Bank	0.68	0.61	0.56	0.54	0.51	0.45	0.45	0.54
One Bank	0.69	0.68	0.55	0.89	0.50	0.60	0.49	0.63
UCB Bank	0.62	0.62	0.61	0.81	0.85	0.86	0.92	0.76
Pubali Bank	0.59	0.56	0.53	0.55	0.52	0.43	0.44	0.52
Priemer Bank	0.38	0.72	0.66	0.67	0.61	0.59	0.54	0.60
Mutual Bank	0.67	0.81	0.88	1.00	0.77	0.87	0.66	0.81
South East Bank	0.91	1.00	0.86	0.94	0.88	0.77	0.72	0.87
Eastern Bank	0.88	0.74	0.57	0.60	0.51	0.52	0.49	0.61
AB Bank	0.98	0.99	0.97	0.83	0.65	0.66	0.57	0.80
Dhaka Bank	0.84	0.80	0.68	0.76	0.70	0.80	0.77	0.77
DBBI	0.85	0.90	0.77	0.76	0.72	0.83	0.64	0.78

Foreign Banks (FBs) it declined sharply and for Private Banks (PBs) it remained almost stable. These results were supported by Mahesh and Meenakshi (2006). However, not all banks belonging to FB showed declining trend in deposits efficiency in the time period. At the bank group level, NBs and ISBS were more efficient with 90.9% and 86.8% respectively followed by PBs with 63.4% and FBs with 62.7% in producing deposits services. This study supported the findings of Dilruba and Khandakher (2005) and Hamim et al (2006) in particular for nationalized commercial banks and for Islamic Banks. From our analysis we observed that the foreign banks were less efficient in producing deposits. It was noted that not all foreign banks were less efficient. For example, the year (2003 and 2005) wise group efficiency of foreign bank in deposits efficiency were 0.722 and 0.669, higher than the corresponding deposits efficiency of private banks. These findings are in line with the argument that foreign banks are superior as they normally have advanced technology and skills; sophisticated services and broader international networks (Levine, 1996; Unite and Sullivan, 2003). The reason for the other years, the foreign banks being less efficiency in producing deposits services could be that majority of them depend mainly on borrowed funds for lending and investment purposes. However, the overall deposits efficiency of all bank groups was steadily increasing over time except in 2007. In 2007 the deposits efficiency remarkably decrease might be due to political unrest, emergency power government and fear of the people to keep their money in the bank. In case of foreign banks, the reason for less efficient was their lower fixed assets compared to other banks. Domestic banks were relatively more efficient than foreign banks. These results are supported by the findings of Iza et al. (2009).

The bank-wise efficiency was reported in Table 6 and in Figure 3. We observed that Islami Bank Bangladesh Ltd and Government Owned Sonali Bank were most efficient in producing deposits with 96 and 94% respectively. This result indicated that big size (measuring their total assets) banks are comparatively more efficient. But this result contradicted with Islamic banks. This might be due to the fact that people have faith on Islamic banks. On the other hand, Pubali Bank and Uttara Bank were far lower efficient comparing with the above two Banks. It could be that these less efficient banks were concentrating in other services rather than deposits. From our study we found that large size banks were less inefficient than small size banks in producing deposits.

Results on hypothesis tests of deposits stochastic frontier model

The results of various hypothesis tests of deposits model were presented in Table 7. All the hypotheses tests are obtained using the generalized likelihood-ratio statistic (7).

The critical values are obtained from table of Kodde and Palm (1986). The null hypothesis included the restriction that $\gamma = 0$ did not have a chi-square distribution, because the restriction defined a point on the boundary of parameter space.

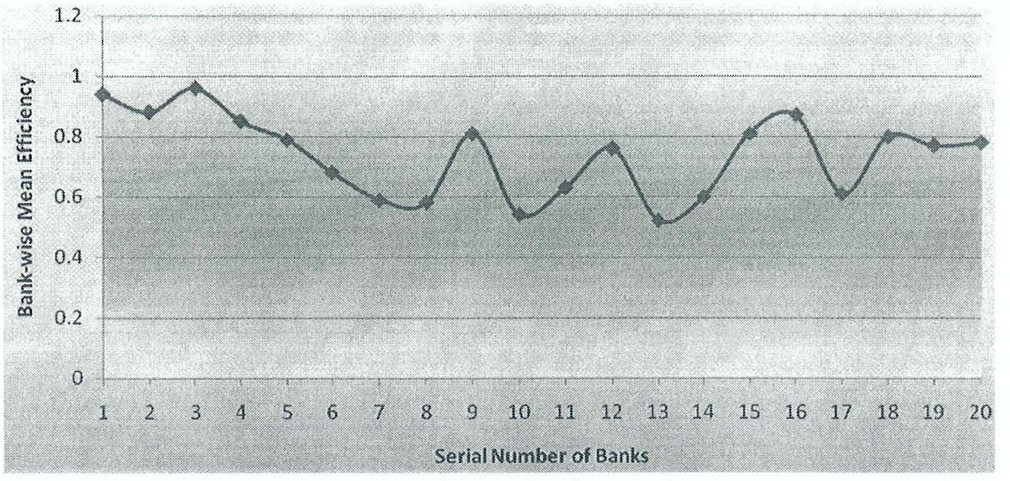

Figure 3. Bank-wise average deposits efficiency in Bangladesh.

Table 7. Generalized likelihood-ratio test of hypothesis of the deposits stochastic frontier production model.

Null hypothesis	Log-likelihood function	Test statistic λ	Critical value*	Decision
$H_0 : \gamma = 0$	21.94	68.99	3.38	Reject H_0
$H_0 : \beta_{ij} = 0$	-20.26	166.01	19.35	Reject H_0
$H_0 : \eta = 0$	21.94	126.965	3.38	Reject H_0

*All critical values are at 5% level of significance.

The estimates of variance ratios $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$ of deposits model was found to be 0.999. The first null hypothesis is $H_0 : \gamma = 0$, which specified that there was no technical inefficiency effect in the deposits model. Since the hypothesis was rejected so we concluded that there was a technical inefficiency effect in the model.

The second null hypothesis is $H_0 : \beta_{ij} = 0$, which indicated that Cobb-Douglas Production Function was preferable to Translog Production Function. From the outcome it was observed that the null hypothesis was strongly rejected and Translog Production Function was statistically more favorable.

The third null hypothesis is $H_0 : \eta = 0$, which specified that the technical inefficiency effect did not vary significantly over time. The null hypothesis was rejected indicating that the technical inefficiency effect varied significantly.

POLICY RECOMMENDATIONS

Bank efficiency studies are of crucial importance for operational and academic proposes (Berger et al., 1997). Efficiency evaluation is useful for individual investment or loan decisions. In addition, creditors and investors use such efficiency evaluations to judge past performance and current position of banks. Second, to judge future potential and the risk connected with that potential. Consequently, drawing efficiency results of banks can help improve their overall investment performance. It is a matter of significant importance to know whether decisions regarding adoption of the innovative technology in banking constitute one of the prime factors in determining banks' performance and growth. The findings of the study have important policy implications for efficiently managing the financial institutions, especially the NB, ISB and PB banks. In particular, the NB should take appropriate actions for increasing their coverage in offering innovative technology driven services with a view to increasing their performance and raising their market competitiveness. Banks can provide efficient banking services to the nation if they are supported with appropriate banking laws, and regulations. It would be better if banks had the opportunity to work as a sole system in an economy. That would provide banking system to fully utilize its potentials. Studies show that Islamic banks cannot operate within their full efficiency level and if they operate under a conventional banking framework, their efficiency goes down in a number of dimensions.

It would be important for financial sector policies to encourage the banks to use any excess liquidity in the banking system for providing credit to productive activities. The Bangladesh Bank, being the regulator of the financial system, can play an important role through taking necessary measures to expedite the initiatives of the traditional banks in adopting such innovative technology driven products and services in their banking activities. On its part, this bank should strengthen its prudential oversight and closely monitor the liquidity situation in the banking system. In addition, it would be important for the Bangladesh Bank to continue its efforts in urging the banks to reduce their lending rates, increase competition among the financial intermediaries, and pursue strong monitoring and supervision measures so that the financial institutions reduce administrative cost by improving efficiency and reducing the burden of nonperforming loans.

Conclusion

This study was set out to provide the estimates of the bank specific deposits efficiency and to compare efficiency estimates for NBs (National Banks), ISBs (Islamic Banks), FBs (Foreign Banks), and PBs (Private Banks) of Bangladesh using stochastic frontier analysis. We compared the efficiencies of 20 Commercial Banks group wise, year wise and specific bank wise for the time period of 2001 to 2007. The most important results were summarized thus:

(1) First, we analyzed the Translog Stochastic Frontier Production Function with distributional assumptions for the measurement of bank specific deposits efficiency and the presence of one-sided error component was justified by the LR test individually, which was highly significant for deposits Translog stochastic frontier model. We found that the technical inefficiency declined over the reference period and Translog Production Function was preferable to Cobb-Douglas Production Function.

(2) From the estimates of deposits model we found that the coefficient of material input variable showed a negative sign, indicating that banks using less material (Stationary, postage, and other materials) were more productive. In deposits inefficiency effects model, the coefficient of total assets contains negative sign, indicating that the more the total asset the more the bank efficiency. The coefficients of NBs and ISBs demonstrate negative sign, implying that inefficiency level declines when competition increases.

(3) The estimated year wise average efficiency of the sample banks from the deposits model was 0.738 while group wise average technical efficiency is 0.777. At the bank group level, Nationalized Commercial Banks (NBs) and Islami Banks (ISBS) were more efficient by 90.9 and 86.8% respectively followed by Private Banks (PBs) 63.4% and Foreign Banks (FBs) with 62.7% in producing deposits services. From our analysis we observed that the foreign banks were less efficient in producing deposits. However, the overall deposits efficiency of all bank groups was steadily increasing over time except in 2007. The most efficient bank was Islami Bank Ltd. and the most inefficient bank was Pubali Bank with efficiency scores of 0.96 and 0.52, respectively.

ACKNOWLEDGEMENT

The authors wish to acknowledge the support provided by Research University Grant Scheme, No. 1001/PJJAUH/811130, Universiti Sains Malaysia, Penang, Malaysia for conducting this research.

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Scientific Research and Essays Vol. 5(11), pp. 1234-1242, 4 June, 2010
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 ©2010 Academic Journals

Full Length Research Paper

A stochastic frontier approach for empirical tests of efficiency wage models

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Accepted 21 May, 2010

This paper was aimed at testing the validity of wage efficiency hypothesis in developing country through the impact of a wage efficiency policy on the relative technical efficiency of firms. We used wage augmented stochastic production frontier models to measure technical efficiency of food manufacturing industry using an unbalanced panel data set over the period 1988 - 1989 to 1999 - 2000. The wage augmented Cobb Douglas production function was found to be an inadequate representation of the data compared to wage augmented Translog frontier model. Our empirical analysis showed that the elasticity of the efficiency wage function of employee was, on average, -0.555 while that of operative was -0.039. The results indicated that wage efficiency policy was not valid for a developing country like Bangladesh. The mean technical efficiency was estimated 0.398 implying that only 39.8% of the potential output is being realized in this sector.

Key words: Efficiency wage, stochastic frontier production function, technical efficiency.

INTRODUCTION

The efficiency wage model asserts that the productivity of workers in firms is positively correlated with the wages they receive. Most efficiency wage theories assume that productivity depends on the relative wage inside and outside the firm. The Solow and Shapiro-Stiglitz models argued that paying higher wages lead to greater individual work effort and raise firm or industry output or productivity (Solow, 1979; Shapiro and Stiglitz, 1984). The efficiency wage model is particularly important for developing countries since, if valid, it raises important questions regarding the effectiveness of stabilization and structural adjustment policies (Riveros and Bouton, 1994). So, it is necessary to determine whether the efficiency wage is a useful explanation of this stylized fact at the industry level or not.

A number of studies have shown that there exists a link between the level of wages in a firm and labor efficiency. The wage efficiency hypothesis which can be justified on several grounds (Akerloff and Yellen, 1986), cannot be ruled out, that is other things being equal, firms paying higher wages benefit from a more efficient labor input. Konings and Walsh (1994) looked to discriminate between the efficiency wages and rent sharing hypo-theses by investigating the relationship between market shares and wages. Downes and Leon (1994) found that the wage rate has no direct impact on labor productivity in Barbados. Riveros and Bouton (1994) found supportive evidence for the efficiency wage hypothesis by analyzing wage differentials across firms in the manufacturing sector in Sao Paulo, Brazil. Francis Teal (1995) used the relative wage terms in a productivity equation to test for efficiency wages. Huang et al. (1998) recognized that both the observable and unobservable components of human capital can explain the wage- productivity nexus.

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JEL classification: C12, C13, C23, C24, J41.

Bouabdallah et al. (2004) examined the relationship between unemployment and working hours in the context of an efficiency wage model and proved that work sharing may have a reducing impact on unemployment.

Although the efficiency wages hypothesis seemed consistent with several empirical facts, the literature of personnel economics and research on motivation (see, for instance, Snowdon et al., 1994; Lazear, 2000; Goldsmith et al., 2000), the hypothesis faces some serious theoretical and empirical challenges. Two major results in testing for efficiency wages using production functions are those of Wadhwani and Wall (1991); Levine (1992), who found that relatively high wages in the firm are associated with high productivity. Fidelis (1992) applied the effort-augmented production function of the efficiency wage model on analysis of monopoly wage and employment. Seref Saygili (1998) tested the validity of the efficiency wage hypothesis by using firm level data from a developing country, namely Turkey. Sergio and Contreras (2003) used the econometric frontier approach to estimate efficiency measures of the transformation of human capital into earned income in the Chilean labor market. Atul (2007) empirically investigated the extent of labor market inefficiency by using the stochastic frontier model.

At present, there are no industry level studies that tests for the efficiency wage model using stochastic frontier approach in Bangladesh. The purpose of this study is to test the validity of the efficiency wage hypothesis by using a wage augmented stochastic production frontier for firm level data of Bangladesh food industry. We devote to estimate firm level technical inefficiency as the performance measure and investigated whether the wage is a significant determinant of the firm's inefficiency or whether the most technically efficient firms are necessarily at an optimum from the efficiency wage policy point of view. This study confirms the predictions of the efficiency wage hypothesis. We show that whether the Solow condition does hold in this study.

The paper is organized as follows. Section 2 described the basic efficiency wage efficiency model in brief and discussed estimation techniques which are used to assess the performance of a firm's efficiency. The data and methodology of this study are discussed in section 3. The empirical results were presented in section 4 and finally the concluding remarks are summarized in section 5.

MATERIALS AND METHODS

The wage efficiency model and estimation techniques

There are different versions of efficiency wages models, but in this paper we are mainly interested in basic efficiency wage model and in its simplest form, the efficiency wage hypothesis can be summarized by a production function of the form:

$$Y = f\left(e(w)L\right), \quad e(w) > 0$$

Where:
Y is the output or production,
L is the number of workers,
w is the real wage and
e is the effort per worker, or more general, worker productivity and $e(w)$ is the efficiency or effort function which depend on the wage w.

Under the assumption that the effective labor input is the product of effort and employment, it can be shown that the elasticity of effort with respect to the wage level is unity (Solow, 1979). If the efficiency or effort function is such that $e'(w) > 0$ and $e''(w) < 0$, it can be shown that the optimal behavior of firm is to put the wage at a level where the elasticity of $e(w)$, the efficiency function, with respect to the wage, equals unity,

$$\xi_{e|w} = \frac{\partial e(w)}{\partial e} \cdot \frac{w}{e} = 1 .$$

Two different forms of estimating wage efficiency model have been devised. One is the deterministic frontier and the other is the stochastic frontier. The deterministic frontier approach proposed by Greene (1980) was rather restrictive and perhaps misleading since it may confound inefficiency with the effects of under specification and measurement errors. The stochastic frontier production function with composed errors has been increasingly used by researchers (Caves, 1992; Perelman, 1995; Battese et al., 1996). The most important advantage of this method over the more traditional methods was that it takes into account the distinction between the two main sources of productivity growth, namely technological progress and efficiency change.

Stochastic Production Frontiers

The stochastic frontier production function for the measurement of technical efficiency was first proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). The ith firm specific stochastic output frontier production function at the time t can be written as:

$$Y_{it}^* = \exp(\beta_0 + \beta X_{it} + v_{it} - u_{it}) \qquad i = 1,2,3......N; \quad t = 1,2,3.......T$$

Where:
Y^* is the output variable,
X is the vector of input variables,
β is a vector of parameters, the random variable,
u_{it}, follows a normal distribution with mean μ and variance σ_u^2

Table 1. Variables and summary statistics.

Variable	Definition	Mean	Standard deviation
Y (in TK million)	Gross output: Gross output is the value of products and by-products, plus receipts for work done and for services to others, plus net change in work-in-progress. Products and by-products are valued at the ex-factory prices, including excise duty, sales tax and other indirect taxes.	3151.13	3330.19
K (in TK million)	Total fixed assets: Total fixed assets mean all assets, whether obtained from other enterprises or produced by the establishment out of its resources for its own use, which are expected to have a productive life of more than one year. It consists of land, buildings, other construction, machinery tools and equipment, transport etc.	666.16	715.79
E (in TK million)	Employee: Employee includes all classes of permanent and salaried employees of the establishment such as managers, clerks, typists and other administrative workers.	7.95	8.96
O (in TK million)	Operative: Operative means those who are engaged directly in the production process and includes those engaged in manufacturing, assembling, packing, repairing etc. Working supervisors and persons engaged for repair and maintenance are also included.	5.65	6.42
T	Year: Year is the year of observation where T = 1, 2, 3, 4, 5, 6, 8, 10, 12 for the years 1988-1989, 1989-1990,1990-1991,1991-1992,1992-1993,1993-1994,1995-1996,1997-1998 and 1999-2000 respectively		
RWE	Wage of employee relative to food industry	1.007	1.529
RWO	Wage of operative relative to food industry	1.0	1.385
	Real Wage for employee (in TK million)	162.95	247.67
	Real Wage for operative (in TK million)	94.91	134.35

Source: Bangladesh Bureau of Statistics (BBS), Year Books (for 1988-1989 to 1999-2000).

with non-negative truncations and v_{it} is distributed normally with mean zero and variance σ_v^2 . u_{it} and v_{it} are assumed to be independently distributed for all i and t.

Then the technical efficiency level of firm i at time t is the ratio of the actual to the potential output (Kumbhaker and Lovell, 2000; Taymaz and Saatci, 1997) as given below:

$$TE_{it} = \frac{\exp\left(\beta_0 + \beta X_{it} + v_{it} - u_{it}\right)}{\exp\left(\beta_0 + \beta X_{it} + v_{it}\right)} = \exp(-u_{it}).$$

In particular, the efforts of managers and workers allowed to determine the level of inefficiency (Aigner et al., 1977) and, accordingly, the efficiency wage hypothesis can be tested by including the wage level amongst the set of variables determining the level of inefficiency.

DATA AND METHODOLOGY

The data used in this study is drawn from the Census of Manufacturing Industries (CMI), and Bangladesh Bureau of Statistics (BBS) every year. The study area covered 4-digited census factories, under registered manufacturing sectors of Bangladesh over the reference period 1988 - 1989 to 1999 - 2000. As data for three years, viz. 1994 - 1995, 1996 - 1997 and 1998 - 1999 were not published; data for the remaining 9 years are considered for this study. The estimates at constant prices (1988 – 1989 = 100) are derived.

Following CMI reports, we have an unbalanced sample of 17 different firms for food manufacturing firm or industry. These are: manufacturing of dairy products (3112); processing of fruits and vegetables (3113); processing of fish and sea foods (3114); manufacturing of hydrogenated vegetables oil (3115); edible, vegetable oil except hydrogenated oil (3116); inedible vegetable oil, animal oil (3117); grain milling except rice milling (3118); rice milling (3119); grain mill products N.E.C. (3121); manufacturing of bakery products (3122); manufacture of sugar (3123); Manufacture of Gur (3124); cocoa, chocolate and confectionary (3125); tea, coffee processing (3126); tea and coffee blending (3127); extraction of edible salt (3128) and misc. food, macaroni, noodles (3129); both grain mill products N.E.C. and manufacture of gur firms are excluded from this study since they do not satisfy the normality assumption of the dependent variable. One reason for violating the assumption of that the technologies used by these two firms are heterogeneous with others. Moreover, since four observations appear as outliers, so they are not considered also. Thus, the data involved in this study is a total of 131 observations. Variable and summary statistics are given in Table 1.

Wage augmented stochastic production frontiers

There are basically two common functional forms used here as stochastic frontier production functions, namely Cobb-Douglas and Translog functional form. A wage augmented Cobb-Douglas frontier production function where the wage efficiency assumption is taken into account by including both the relative wage of employee (RWE) and relative wage of worker (RWO) can be written as follows:

$$\ln Y^{*}_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln E_{it} + \beta_3 \ln O_{it} + \beta_4 T + \beta_5 \ln RWE_{it} + \beta_6 \ln RWO_{it} + v_{it} - u_{it} \quad (1)$$

Where:

Y^{*}_{it} is the gross output of firm i at time t,

K_{it} is the total fixed assets,

E_{it} is the employee,

O_{it} is the operative,

T is a time trends.

Here we split the workforce into two categories, the employee (E) and operative (O). These two groups have specific efficiency functions considered so that we include the relative wages of these two categories in the production function that is relative wage for employee (RWE) and relative wage for operative (RWO), and a composed error structure for the stochastic term is as suggested by Battese and Coelli (1993).

Since the Cobb-Douglas specification is nested in the Translog model and the Translog functional form is flexible and it imposes fewer restrictions on the data, therefore in this paper we have also considered the following form of wage augmented Stochastic Translog production frontier function:

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln E_{it} + \beta_3 \ln O_{it} + \beta_4 T + \beta_5 \ln RWE_{it} + \beta_6 \ln RWO_{it} + \beta_{11}(\ln K_{it})^2 + \\ &\beta_{22}(\ln E_{it})^2 + \beta_{33}(\ln O_{it})^2 + \beta_{44}T^2 + \beta_{55}(\ln RWE_{it})^2 + \beta_{66}(\ln RWO_{it})^2 + \beta_{12}(\ln K_{it})(\ln E_{it}) + \\ &\beta_{13}(\ln K_{it})(\ln O_{it}) + \beta_{14}(\ln K_{it})T + \beta_{15}(\ln K_{it})(\ln RWE_{it}) + \beta_{16}(\ln K_{it})(\ln RWO_{it}) + \\ &\beta_{23}(\ln E_{it})(\ln O_{it}) + \beta_{24}(\ln E_{it})T + \beta_{25}(\ln E_{it})(\ln RWE_{it}) + \beta_{26}(\ln E_{it})(\ln RWO_{it}) + \beta_{34}(\ln O_{it})T + \\ &\beta_{35}(\ln O_{it})(\ln RWE_{it}) + \beta_{36}(\ln O_{it})(\ln RWO_{it}) + \beta_{45}T(\ln RWE_{it}) + \beta_{46}T(\ln RWO_{it}) + \\ &\beta_{56}(\ln RWE_{it})(\ln RWO_{it}) + v_{it} - u_{it}\end{aligned} \quad (2)$$

In this above specification if the second-order terms, β, are all equal to zero then the model reduces to standard Cobb-Douglas form (1). The inclusion of year of observation as a variable allows for the shifts of the frontier over time, which is interpreted as technical change.

Estimation of both the wage augmented production frontier models are obtained by FRONTIER Version 4.1 program (Coelli, 1996). The parameters of the frontier models are estimated, such that the variance parameters are:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$ and

$$\gamma = \sigma_u^2 / \sigma^2$$

where the γ parameter has a value between zero and one.

Now, using the estimated values of the Translog production function (2), we have computed the following elasticities of output to changes in the various inputs, (omitting the indexes i and t)

$$\xi_{Y|RWE} = \beta_5 + 2\beta_{55} \ln RWE + \beta_{15} \ln K + \beta_{25} \ln E + \beta_{35} \ln O + \beta_{45} T + \beta_{56} \ln RWO \quad (3)$$

And

$$\xi_{Y|RWO} = \beta_6 + 2\beta_{66} \ln RWO + \beta_{16} \ln K + \beta_{26} \ln E + \beta_{36} \ln O + \beta_{46} T + \beta_{56} \ln RWE \quad (4)$$

Similarly, we obtained the following elasticities of output

$$\xi_{Y|E} = \beta_2 + 2\beta_{22} \ln E + \beta_{12} \ln K + \beta_{23} \ln O + \beta_{24} T + \beta_{25} \ln RWE + \beta_{26} \ln RWO \quad (5)$$

And

$$\xi_{Y|O} = \beta_3 + 2\beta_{33} \ln O + \beta_{13} \ln K + \beta_{23} \ln E + \beta_{34} T + \beta_{35} \ln RWE + \beta_{36} \ln RWO. \quad (6)$$

Then, we can obtain the following measure of the elasticities of the labor efficiency function

$$\xi_{Y|RWE} = \xi_{Y|e} \cdot \xi_{e|RWE} \text{ and } \xi_{Y|RWO} = \xi_{Y|e} \cdot \xi_{e|RWO}$$

and noting that $\xi_{Y/e} = \xi_{Y/E}$ and $\xi_{Y/e} = \xi_{Y/O}$ as long as, as usually assumed (Solow, 1979), the production function is initially expressed in terms of the efficient amount of labor, which is obtained by multiplying the physical measure of labor (here the number of employee and the number of operative) engaged by the efficiency functions $e(RWE)$ and $e(RWO)$ respectively. Then, without assuming any particular form of the efficiency wage function (Levine, 1992), and indeed, in order to answer the question of the possible existence of a difference between the maximum and the optimal productive efficiency of firms, we have obtained the elasticities of the efficiency functions for two groups of workers (employee and operative) with respect to their relative wages:

$$\xi_{e|RWE} = \frac{\xi_{Y|RWE}}{\xi_{Y|E}} \quad (7)$$

and

$$\xi_{e|RWO} = \frac{\xi_{Y|RWO}}{\xi_{Y|O}} \quad (8)$$

respectively.

RESULTS AND DISCUSSION

A simple log-likelihood test indicated that the restrictions imposed by the Cobb-Douglas production function are not supported by the data. Furthermore, with regard to the specification of the error term, the estimation results showed that the traditional production function is strongly rejected, implying that the technical inefficiency effects associated with this industry is significant. The results indicated that the technical inefficiency effects tend to decline over time since the estimate for the η parameter is positive (that is. $\hat{\eta} = 0.039$) and significant. However, the γ -estimate associated with the variance of the technical inefficiency effect is large and significant. The relevant test is simply a test of $H_0 : \gamma = \sigma_u^2 / \sigma^2 = 0.$

The maximum likelihood estimates of wage augmented Cobb-Douglas and Translog production function are presented in Table 2. The parameter estimates for employee is positive while that for operative turns to be negative. This implied that as the number of employee increases, output increases but as operative increases output decreases. These two estimates as a whole support the "shirking" variant of efficiency wage hypothesis. Because the supervisory intensity has same direction with number of employee but it is opposite direction with operative. The estimated coefficient of relative wage for operative appears to be positive, as it was expected, implying that the output increases with the increment of relative wage for operative. This estimate confirmed our primary prediction of efficiency wage hypothesis. But the coefficient of relative wage for employee turns to be negative which is surprising. Our estimation results also showed that the Solow condition does not hold since the coefficients of the relative wage levels for employee and operative are significantly different than the coefficients of the employee and operative respectively. This implied that the estimated elasticity of effort with respect to wages is less than one. In addition, from the estimated parameter values of Cobb-Douglas production function what we observed that the coefficient of employee, operative, wage of operative relative are found to be significantly affect in the food manufacturing productivity whereas the variables capital, time and wage of employee relative are found to be insignificant. On the other hand, for the Translog production function case, the variables capital, wage of operative relative, square terms of wage for employee relative and wage for operative relative, interaction in capital with wage for employee relative and wage for operative relative and interaction in between wage for employee relative and wage for operative relative are found to be significant affecting the productivity of food manufacturing firms. Simultaneously, the variables employee, operative, time, square term of operative, square term of time, interaction in capital with employee, operative, time, interaction in employee with wage of employee relative and wage of operative relative do not affect to the productivity process significantly in food manufacturing firms.

The elasticities of output to changes in the various inputs are estimated in Table 3. These estimates being firm specific, we evaluated them, for each firm at its own mean value of the variables. Although there is some variation in the individual estimates, these elasticities take quite plausible values. The elasticity of mean output with respect to operative and relative wage for operative are being estimated as -0.842 and 0.008 respectively. These estimates implied that output is a decreasing function of number of operative but increasing function of relative wage for operative. On the other hand, an opposite situation is observed for employee and their relative wage. In this case, output changes in the same direction of number of employee but in the opposite direction of relative wage for employee. Although the elasticity of mean output with respect to operative, relative wage for employee and relative wage for operative showed decreasing return to scale but the mean output elasticity for employee appeared as 1.493 with increasing returns to scale.

The mean elasticity of effort with respect to relative wage of employee and relative wage of operative along with mean technical efficiency are presented in Table 4. The results indicated that the elasticities of the efficiency functions of both employee and operative are negative. This is on average -0.555 and -0.039 for employee and operative respectively. The results implied that efficiency of the worker is a decreasing function of relative wage with decreasing returns to scale. This fact, in turns, does not support the existence of efficiency wage hypothesis. The overall mean technical efficiency is estimated to be 0.398 for the food manufacturing industry of Bangladesh, which implies that only 39.8% of the potential outputs are being realized in food manufacturing industry sector. There is a wide variation in the technical efficiencies among the different firms of food manufacturing industry. The mean technical efficiency implies that the food manufacturing industry is not realizing 100% of its potential output. The value of λ , which tests the existence of inefficiency, also confirmed the results.

In addition, we observed from the Table 5, that the elasticity of the efficiency function of employee is above unity while that of other input variables are, on the contrary, below unity. Finally we observed from the Table 6, that the elasticity of the efficiency function of wage of

Table 2. Maximum-likelihood estimates for parameters of the wage-augmented production frontier.

Variable	Cobb-Douglas		Translog	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	9.593*	6.559	0.206	0.016
K	0.092	1.220	2.044***	1.530
E	1.207*	5.320	0.432	0.071
O	-0.484**	2.288	-1.051	0.190
T	-0.002	0.096	-0.084	0.537
RWE	0.118	0.891	-2.781	1.148
RWO	-0.169***	1.331	3.492***	1.414
K^2	-	-	-0.151*	2.709
E^2	-	-	-0.806***	1.560
O^2	-	-	-0.623	1.224
T^2	-	-	-0.005	1.266
RWE^2	-	-	0.932**	2.145
RWO^2	-	-	0.945*	2.450
$K*E$	-	-	0.282	0.534
$K*O$	-	-	-0.019	0.043
$K*T$	-	-	0.018***	1.308
$K*RWE$	-	-	0.311***	1.487
$K*RWO$	-	-	-0.285***	1.373
$E*O$	-	-	1.303***	1.633
$E*T$	-	-	0.039	0.599
$E*RWE$	-	-	-0.312	0.283
$E*RWO$	-	-	-0.193	0.167
$O*T$	-	-	-0.056	0.908
$O*RWE$	-	-	0.107	0.101
$O*RWO$	-	-	0.324	0.294
$T*RWE$	-	-	-0.045	0.856
$T*RWO$	-	-	0.033	0.640
$RWE*RWO$	-	-	-1.897**	2.320
σ^2	0.719**	1.881	0.535**	1.906
γ	0.811*	8.100	0.814*	8.140
η	0.031**	1.917	0.039**	1.965
λ	133.205		124.856	
$Log-likelihood$	-81.801		-61.756	

* means significant at 1%, * * means significant at 5%, * * * means significant at 10%

Note: $\lambda = -2\{\ln[\ln(H_0) - \ln(H_1)]\}$ is generalized likelihood-ratio (LR) statistic where $\ln\{L(H_0)\}$ and $\ln\{L(H_1)\}$ are the values of the log-likelihood function for the frontier model under the null and alternative hypothesis.

Source: Author's computation

Table 3. Firm level elasticities of output.

Industry code	Elasticity of output with respect to				
	Employee	Operative	Relative wage for employee	Relative wage for operative	Capital
3112	1.831 (0.268)	-0.943 (0.168)	-0.107 (0.302)	0.087 (0.293)	-0.046 (0.124)
3113	2.338 (0.442)	-1.355 (0.548)	-0.107 (0.672)	0.175 (0.698)	-0.079 (0.440)
3114	2.295 (0.702)	-1.326 (0.620)	0.206 (0.487)	-0.238 (0.456)	-0.090 (0.130)
3115	1.791 (0.336)	-0.898 (0.335)	0.356 (0.233)	-0.355 (0.262)	-0.025 (0.124)
3116	1.668 (0.334)	-0.806 (0.294)	-0.057 (0.490)	-0.035 (0.459)	-0.068 (0.114)
3117	1.827 (0.557)	-1.204 (0.483)	-0.463 (0.317)	0.522 (0.294)	0.331 (0.140)
3118	1.396 (0.631)	-0.682 (0.528)	-0.038 (0.263)	-0.088 (0.269)	0.114 (0.151)
3119	2.012 (0.795)	-1.311 (0.711)	0.097 (0.252)	-0.199 (0.247)	0.170 (0.118)
3122	0.938 (0.400)	-0.590 (0.371)	-0.318 (0.368)	0.174 (0.351)	0.483 (0.145)
3123	-0.118 (0.317)	0.540 (0.310)	-0.368 (0.382)	-0.076 (0.379)	0.296 (0.115)
3125	0.650 (0.639)	-0.400 (0.558)	-0.810 (0.337)	0.735 (0.341)	0.616 (0.092)
3126	0.903 (0.710)	-0.264 (0.587)	0.400 (0.356)	-0.549 (0.409)	0.115 (0.113)
3127	1.671 (0.949)	-1.033 (0.821)	-0.445 (0.450)	0.415 (0.354)	0.325 (0.244)
3128	1.195 (0.773)	-0.897 (0.657)	-0.227 (0.694)	0.163 (0.639)	0.612 (0.143)
3129	2.001 (0.692)	-1.455 (0.867)	0.600 (1.254)	-0.607 (1.232)	0.471 (0.457)
Mean	1.493 (0.672)	-0.842 (0.521)	-0.086 (0.376)	0.008 (0.377)	0.215 (0.253)

Note: Numbers in parentheses are standard errors.

Table 4. Statistics about the estimated firm level elasticities of output

Elasticity	Mean	Std. Dev.	Minimum	Maximum
$\xi_{Y/E}$	1.4930	0.6719	-0.1180	2.3380
$\xi_{Y/O}$	-0.8416	0.5214	-1.4550	0.5400
$\xi_{Y/RWE}$	-8.5E-02	0.3754	-0.8100	0.6000
$\xi_{Y/RWO}$	8.27E-03	0.3766	-0.6070	0.7350
$\xi_{Y/K}$	0.2150	0.2528	-0.0900	0.6160

employee relative and wage of operative relative are, below unity.

Conclusion

In this study, we tested the implications of the wage efficiency hypothesis for the food manufacturing industry of Bangladesh. We estimated both Cobb-Douglas and Translog production function including an efficiency wage argument. Translog production function was found to be more appropriate than Cobb-Douglas production function for this industry. It also allowed us to take into account firms' heterogeneity in a better way. The elasticities of the efficiency function of both employee and operative were negative implying that the efficiency of the worker was a decreasing function of relative wage with decreasing returns to scale. Thus, the wage efficiency hypothesis did not exist in Bangladesh Food Industry. Our results also showed that the coefficient of relative wage for operative appears to be positive, as expected, but for employee it turned to be negative, which is surprising. The mean technical efficiency for food manufacturing industry was found only 39.8%, which implied that the industry is not realizing 100% of its potential output. The technical efficiency affected tends to increase over time and there existed a significant positive link between wages and the

Table 5. Firm level elasticities of effort.

Industry code	Elasticity of effort with respect to relative wage for		Technical efficiency
	Employee	Operative	
3112	-0.064 (0.157)	-0.092 (0.299)	0.218
3113	-0.033 (0.285)	0.019 (0.599)	0.134
3114	0.118 (0.212)	0.284 (0.421)	0.861
3115	0.216 (0.147)	0.524 (0.461)	0.856
3116	-0.054 (0.319)	-0.064 (0.684)	0.652
3117	-0.256 (0.173)	-0.452 (0.260)	0.516
3118	0.001 (0.225)	0.689 (1.308)	0.520
3119	0.035 (0.224)	0.175 (0.461)	0.273
3122	-0.566 (0.755)	-0.921 (1.624)	0.248
3123	-6.410 (16.891)	0.095 (0.582)	0.256
3125	-0.633 (1.538)	-1.710 (2.092)	0.170
3126	1.573 (2.266)	2.758 (8.590)	0.167
3127	-1.719 (4.309)	-0.811 (1.918)	0.693
3128	-0.701 (1.152)	-1.162 (2.154)	0.254
3129	0.170 (0.566)	0.075 (0.755)	0.150
Mean	-0.555 (1.758)	-0.039 (1.016)	0.398

Note: Numbers in parentheses are standard errors

Table 6. Statistics about the estimated firm level elasticities of effort.

Elasticity	Mean	Std. Dev.	Minimum	Maximum
$\xi_{e/RWE}$	-0.5548	1.758	-6.410	1.573
$\xi_{e/RWO}$	-4.0E-02	1.016	-1.710	2.758

Source: Author's computation.

output in this industry.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support provided by Research University Grant, No. 1001/PJJAUH/811130, Universiti Sains Malaysia, Penang, Malaysia for conducting this research.

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African Journal of Business Management Vol. 4(13), pp. 2718-2727, 4 October, 2010
Available online at http://www.academicjournals.org/AJBM
ISSN 1993-8233 ©2010 Academic Journals

Full Length Research Paper

Adoption of e-banking in Bangladesh: An exploratory study

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Accepted 10 June, 2010

Nowadays e-commerce, e-business and financial services industry have increasingly become a necessary component of business strategy and a strong catalyst for economic development. As a third-world developing country, Bangladesh is far behind to reach the expected level in global banking system. So it is our urgent need to upgrade its banking system. This study has been done mainly based on primary and secondary sources of data or information, which included different publications. This paper is aimed at to determine the present scenario of e-banking and banking sectors in Bangladesh and at the same time it demonstrated the scope and benefits of e-banking compared with the existing system. This paper addressed significant gaps in existing knowledge about the internet banking and landscape. We tried to present actual situation of e-banking in the marketing point of view in Bangladesh. The results showed that e-banking serves several advantages to Bangladeshi banking sector, however, this study also observed that the Bangladeshi customers have not enough knowledge regarding e-banking which is rendering by banking sector in Bangladesh. A discussion of the implications of these results and limitations are provided at the end.

Key words: Banking sector, e-banking, economy, Bangladesh.

INTRODUCTION

E-banking is now a global phenomenon. It is an invaluable and powerful tool driving development, supporting growth, promoting innovation and enhancing competitiveness (Kamel, 2005 and Nath, Shrick and Parzinger, 2001). Technological innovations have been identified to contribute to the distribution channels of banks and these electronic delivery channels are collectively referred to as electronic banking (Goi, 2005). The evolution of banking technology has been driven by changes in distribution channels as evidenced by automated teller machine (ATM), Phone-banking, Tele-banking, PC-banking and most recently internet banking (Chang, 2003; Gallup Consulting, 2008). The developed country as a part and parcel of their economy is now using electronic banking or online banking. There have already been a number of studies related to Internet banking covering a range of research dimensions. For example, Pyun et al. (2002) in the U.S., Japan and Europe, Gurau (2002) in Romania; Sathye (1999) in Australia; Polatoglu and Ekin (2001) in Turkey; Balachandher et al (2000) in Malaysia; and Jasimuddin (2004) in Saudi Arabia focused also related studies of internet banking. Apart from the developed countries, the developing countries are experiencing strong growth in e-banking such as India and the Republic of Korea are experiencing particularly strong growth in e-banking. In Southeast Asia, internet banking is also developing rapidly in Thailand, Malaysia, and Singapore and in Philippines (Mia et al., 2007). We refer also Thulani et al. (2009) in Zimbabwe; Guangying (2009) in China; Dhekra (2009) in Tunisia; Adesina and Ayo (2010); Maiyaki and Mokhtar (2010) in Nigeria; Salehi and Alipour (2010) in Iran, explored the extent of adoption and usage of internet banking. In Nepal, ATMs are the most popular electronic delivery channel for banking services but only

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a few customers are using internet banking facilities.

A strong banking industry is an important in every country and can have a significant affect in supporting economic development through efficient financial services (Salehi and Azary, 2008, Salehi et al., 2008). But there have been several major challenges and issues faced to the e-banking growth and the e-business in general. One major obstacle addressed most is the security concern (Feinman et al., 1999; Financial Service, 2001). Another issue challenged e-business (including e-banking) is the quality of delivery service - including both delivery speed and delivery reliability (Furst et al., 2000). Limited payment options available to online customers are also being complained (Furash, 1994).

As an Internet based technology, e-banking is new and a quite unfamiliar for some people in Bangladesh due to the digital divide and the different level of internet experience and environments. E-banking services have been available in Bangladesh since 2001. As of 2007, 29 out of 48 banks have offered online financial services (Rahman, 2007). In Bangladesh, research has been done on electronic commerce issues (Azam, 2007), computer usage (Azam, 2005), Internet usage (Awal, 2004), telephone (Khan, 2001) and electronic banking (Bakta et al., 2007). The reason for the lack of complete adoption of e-banking in developing countries like Bangladesh is an important research that will be addressed by this paper. In other words, despite this growth of IT Worldwide, Bangladeshi banks continue to conduct most of their banking transactions using traditional methods. Understanding the reasons for the lack of such technological innovation in developing countries such as Bangladesh will develop a fruitful research. The aim of the paper is to look at the emergence, advantages and acceptance of e-banking in Bangladesh. This paper is aimed at to determine economical prospects of e-banking and to explain the present scenario of banking sectors in Bangladesh and at the same time it demonstrates the scope and benefits of e-banking compared with the existing system. This paper also tries to present actual situation of e-banking in the marketing point of view in Bangladesh.

OBJECTIVES OF THE STUDY

The main objectives of this study are as follows:

To shed light on the concept of e-banking.
To examine the present status of existing e-banking in Bangladesh.
To know the adoption of e-banking in Bangladesh context.

BACKGROUND OF THE STUDY

The definition of e-banking varies amongst researches partially because electronic banking refers to several types of services through which bank customers can request information and carry out most retail banking services via computer, television or mobile phone (Daniel, 1999; Mols, 1998; Sathye, 1999). Burr (1996) describes that it as an electronic connection between bank and customer in order to prepare, manage and control financial transactions.

E-banking is form of banking, where funds are transferred through an exchange of electronic signals between financial institutions, rather than the exchange of cash, checks, or other negotiable instruments. The ownership of funds and transfers of funds between financial institutions are recorded on computer systems connected by telephone lines. Customer's identification is by access code, such as a password or Personal Identification Number (PIN), instead of a signature on a check or other physical document. E-banking involves individual and corporate clients, and includes bank transfers, payments and settlements, documentary collections and credits, corporate and household lending, card business and some others (UNCTAD, 2002).

Banking has never been more important to our society than it is today. The advance of communication and computer technology and the availability of the Internet have made it possible that one can do most banking transactions from a remote location even without stepping into a physical financial structure - that is, the emerging of e-banking (Bruene, 2002). The way Bill Gates (2008) announced that «banking is essential, banks are not». This quotation means that the traditional bank branch is going to vanish in order to be surrogated by electronic banking which continues to attract new users. The banking industry believes that by adopting new technology, the banks will be able to improve customer service level and tie their customers closer to the bank. Meanwhile, the banking industry has been also looking for new methods to expand its customer base and to counteract the aggressive marketing effort of those non-traditional banking entities (Graven, 2000). Larger banks that maintain expensive branch networks tend to have the greatest incentive to adopt e-banking services. In comparison, smaller banks have higher start up costs and tend to have a high initial technological cost in developing e-banking services (Treadwell, 2001).

Many banks quickly realized that there are a momentous number of customers like to do banking electronically. The application of e-banking has been proven as an effective way to reduce the costs of operation for the financial institutions. For instance, e-banking services will allow banks to reduce expenditures on physical structures. It is believed that the e-banking will help banks to cut costs, increase revenue, and become more convenient for customers (Halperin, 2001). Another important benefit from e-banking is a more effective information collection and management. A combination of a low percentage of customers using e-banking services on a consistent basis and a relatively low start-up cost in developing e-banking services in the banking industry will make the impact of e-banking (positive or negative) quite limited on financial institutions (Marenzi et al., 2001). On another hand, e-banking services could be highly demanded and desirable to accommodate the sudden, rapid growth that has occurred in other information-intensive industries such as travel and securities brokerage. Finally, the development of e-banking service has encouraged the adoption of a decentralized approach to give banks more needed flexibility to distribute Internet access to a much larger number of employees and potential customers.

METHODOLOGY

The study has been done mainly based on primary and secondary sources of data or information. The first is an exploratory research based on secondary data obtained through the Net, books and related journals. Secondly, survey questionnaire was administered to empirically assess the level of adoption of e-banking in Bangladesh including different publications: (i) Bangladesh Institution of Bank Management (ii) Bank for International Standard Working (iii) Papers International and local Publications (iv) Different seminar papers (v) Information from Internet (vi) UNCTAD and WTO publication.

Data collection procedure

Primary data sources

Primary data has been collected from Dhaka based some selected banks e.g. Eastern Bank Ltd, Dutch Bangla Bank Ltd. in the year of 2003. These banks are considered as the private commercial banks and foreign banks respectively. Primary dada collections are done by the interviewing method with proper questionnaire.

Secondary data sources

Secondary data has been collected from different publication material and web site as well as the books and material from different libraries, the hand note of the various seminar and research related to the issue are taken into account that includes the library of BIBM, BANBASE, Science Laboratory, DCCI library. The secondary data have been also collected from research material of the following sources; DBBL–Products and Software, EBL–Survey Report, IBA–Feasibility Report, WTO/UNCTAD–Secret of e-commerce.

Sample size determination for e-banking interview

The sample size determination ensures the minimum number of respondents on online Banking. Since there are many indicators the sample size is calculated using 50% as indicator percentage for survey that gives maximum sample size.

The sample size needed was calculated using the following formula:

$$n = z^2\left[p(1-p) \Big/ d^2 \right] \bullet D_{eff}$$

Where n = sample size, z = two-sided normal variate at 95% confidence level (1.96), p = indicator percentage, d = precision and D_{eff} = design effect.

To obtain data on indicators at a 10% precision and 95% confidence interval, assuming a design effect of 1.5 (assumed) and the most conservative estimate of indicator percentage (50%), the minimum sample size required is 150.

Survey design

The present study used a survey that was designed and conducted to find out the feasibility of the e-banking in Dhaka based different national, private commercial banks as well as foreign banks. A specifically designed questionnaire was used as a tool and the survey covered a sample of 150 respondents for the purpose of analysis. These respondents were the customers of various banks; this age group was less then 20, to 25, 26 to 35, 36 to 45 and 46 to 55 and above 56 years. The survey included queries on the following topics:

Income ranges for the customers (per month)
Problem faced regarding service in the bank
Willingness to visit a web site for the relevant information
Willingness to pay fee (Monthly)
Opinion about online banking
Additional services they would like to have.

We used Statistical Package for Social Sciences (SPSS) version 10 as the statistical analysis tool while descriptive statistics were computed and used in the interpretation of findings. The data was presented in the form of tables and graphs.

RESULTS AND DISCUSSION

This section dealt with the results and discussion on both the quantitative and qualitative research based on the primary and secondary data sources.

Adoption of e-banking by respondents

Male respondents were more interested about online banking than female respondents. For that reason most of our respondents are male displayed in Table 1. But the number of females was increasing which was a good sign. At the same it observed that young people adopt the use of Internet more rapidly. Regarding monthly income, Table 2 and Figure 1 showed that the percentages of respondents were found to be higher in case of whose monthly incomes were also more than that of other respondents.

Regarding service in the Bank, Table 3 and Figure 2 revealed that 44% respondents of the total sample size were faced problem in queue and 32% respondents faced hassle to get the telephone lines free in the Bank. It observed that most of the respondents of the total sample size were not willing to pay monthly fees for their service revealed in both Table 4 and Figure 3.

In addition, it found that 119 interviewee which 79.33%

Table 1. Number and percentage of respondents by gender.

Gender	Number	Percentage (%)
Male	87	58
Female	63	42
Total	150	100

Table 2. Number and percentage of respondents whose income per month Tk-000.

Income/Month	No. of respondents	Percentage (%)
Below 15 Tk.	20	13
15 - 20 Tk.	47	31
20 - 30 Tk	29	19
Above 30 Tk.	54	37
Total	150	100

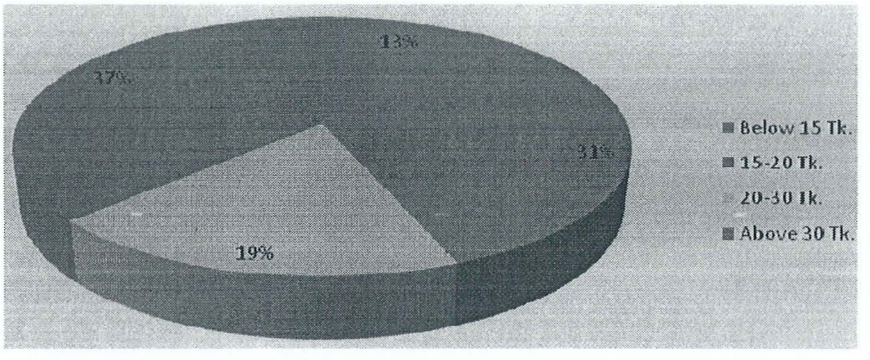

Figure 1. Number and percentage of respondents whose income per month Tk-000.

Table 3. Number and percentage of respondents problem faced in the bank.

Problem faced	No. of respondents	Percentage (%)
Queue problem	67	44.66
Hassle to get the telephone lines free	48	32
Information is not readily available	20	13.34
Lack of confident	15	10
Total	150	100

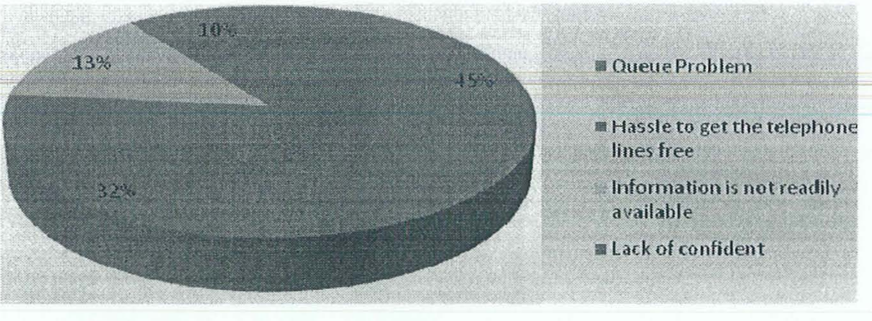

Figure 2. Number and percentage of respondent's problem faced in the bank.

Table 4. Number and percentage of respondents by monthly fees.

Monthly fee	No. of respondents	Percentage (%)
Less than 100	69	46
Tk. 100 – Tk. 200	40	26.67
Tk. 200 – Tk. 300	36	24
Tk. 300 – Tk. 400	5	3.33
Total	150	100

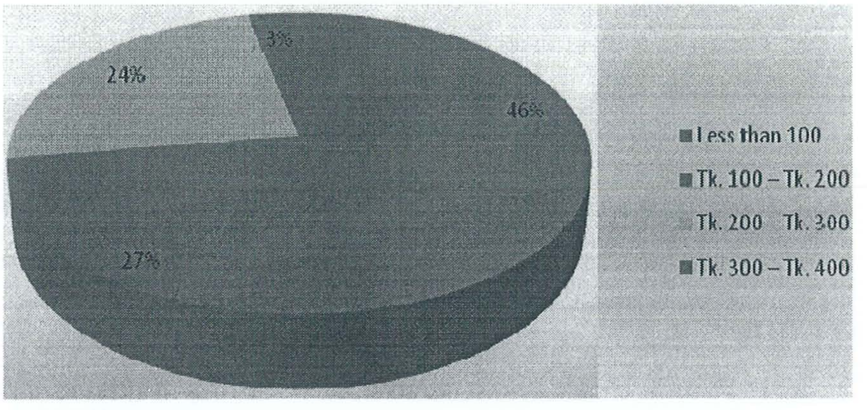

Figure 3. Number and percentage of respondents by monthly fees.

of the total sample size, responded that they needed moderation in operation of the computer. 112 of the interviewee who is 74.66% of the total sample size responded that they were moderated in browsing Internet. 96 of the responded of the total sample size told that they were quite known to the services that were provided in some foreign countries. Literacy results showed that e-banking would not be a tough operation to the people because of their computer knowledge. 89% told that they used to call the bank frequently to their balance. 95% told that they used to know whether the clearing check is cleared or not. 95% of the customers assert that they were willing to pay the utility bill payment through Internet, which would be very convenient for them. The above finding showed that on people's perception about Internet and e-banking are satisfactory.

Present status of e-banking in Bangladesh

E-Banking satisfied customer demand in banking activities electronically throughout the world. At present, several private commercial banks (PCBs) and foreign commercial banks (FCBs) in Bangladesh offered limited services of tele banking, internet banking, and online banking facilities working within the branches of individual bank in a closed network environment. The FCBs played the pioneering role with adoption of modern technology in retail banking during the early 1990s whereas the state-owned commercial banks (SCBs) and PCBs came forward with such services in a limited scale during the late 1990s.

PC banking or PC home banking

PC banking referred to use of personal computer in banking activities while under PC home banking customers used their personal computers at home or locations outside bank branches to access accounts for transactions by subscribing to and dialing into the banks' Internet proprietary software system using password. Basically, PC banking or PC home banking categorized into two types such as online banking and Internet banking.

Online banking: International standard online banking facilities were expanding in Bangladesh. At present, 29 scheduled banks offered any branch banking facilities through their respective bank online network that provided facilities like transaction through any branch under the respective bank online network; payment against paid order or pay order encashment, demand draft encashment, opening or redemption of FDR from any branch of the same bank; remote fund transfer, cash withdrawal, cash deposit, account statement, clearing and balance enquiry within branches of the same bank; and L/C opening, loan repayment facility to and from any branch of respective bank under its own online network.

Internet banking: Internet banking in true sense was still absent in Bangladesh. German banks offered the internet banking since the mid-nineties, although the only product they were offering at the time was information. Only 7 out of 48 banks were providing some banking services via internet that included account balance enquiry, fund transfer among accounts of the same customer, opening or modified term deposit account, cheque book or pay order request, exchange rate or interest rate enquiry, bills payment, account summary, account details, account activity, standing instructions, loan repayment, loan information, statement request, cheque status enquiry, stop payment cheque, refill prepaid card, password change, L/C application, bank guarantee application, lost card (debit/credit) reporting, pay credit card dues, view credit card statement, or check balance.

Mobile banking

Mobile banking was a term used for performing balance checks, account transactions, payments etc. via a mobile device such as a mobile phone. The standard package of activated that mobile banking covers are: mini-statements and checking of account history; alerts on account activity or passing of set thresholds; monitoring of term deposits; access to loan statements; access to card statements; mutual funds/equity statements; insurance policy management; pension plan management; status on cheque, stop payment on cheque; ordering check books; balance checking in the account; recent transactions; due date of payment; PIN provision, change of PIN and reminder over the internet; blocking of (lost/stolen) cards; domestic and international fund transfers; micro-payment handling; mobile recharging; commercial payment processing; bill payment processing; peer to peer payments; withdrawal at banking agent; and deposit at banking agent. Despite huge prospects, only a few banks adopted mobile banking in Bangladesh during the last year.

Tele-banking

Tele-banking service was provided by phone. To access an account it was required to dial a particular telephone number and there were several options of services. Tele banking services widened not enough in daily banking activities in Bangladesh. Only four banks so far provided a few options of tele banking services such as detail account information, balance inquiry, information about products or services, ATM card activation, cheque book related service, bills payment, credit card service and so on. Funds transfer between current, savings and credit card account, stock exchange transactions etc. were still inaccessible through tele-banking in Bangladesh.

E-banking services in Bangladesh

In Bangladesh, credit card and point of sale services (POS) are already provided by a quarter of local banks, while ATM and internet banking were expanding rapidly especially in major cities (Raihan, 2001). According to Rahman (2003), 28 banking software's were in use in different banks in Bangladesh. The foreign banks used foreign software as per their central policies, and these were qualitative and have capability for carrying out e-banking operation. According to Ali et al. (2007), 19 percent of NCBs, 38% of PCBs and 100 percent of the FCBs are computerized. They were around 50 ATMs operating in the country; two foreign banks had several ATMs of their own, two local ATM service providers that offered syndicated or rental service to several banks.

CitiDirect®

The facilities of CitiDirect® were online direct debit transaction process; information reporting; real-time information reporting for more effective cash management; delivered with the highest level of security; easy-to-use application; world link through CitiDirect; comprehensive payment transaction solution; flexible, streamlined functionality; reliability, speed and information; payments through CitiDirect; a comprehensive payments solution globally and locally; simplified, secure transaction management; timely, accurate information; e-mail and wireless banking alerts by CitiDirect.

Standard chartered grindlays bank Ltd

Standard chartered offered the client a comprehensive range of Cash Management services. It provided the secure, reliable and effective link between the client and client's accounts anywhere across the Standard Chartered network.

HSBC: Business banking account enabled a person to receive credit of all the cash or cheque deposits along with inward remittance and made all local payments and provided access to the wide range of services for the business requirements. A person may deposit upto BDT50, 000 cash per transaction and any BDT amount in cheque 24 h a day, 7 days a week through the ATM Machines, conveniently located Sales and Service Centers. EasyPay Machines were also available for deposit of BDT 50,000 cash per transaction and any BDT amount in cheque to the business banking account. With easypay machines, both HSBC and Non-HSBC customers made deposits and pay their utility bills, credit card payments and etc.

Eastern bank limited: Eastern bank limited Internet banking application addressed the needs of small, individual and corporate account holders of the bank. This application provided a comprehensive range of banking services that enabled the customer to meet most of their banking requirements over the net. The transactions that were supported by the internet banking provided by Eastern Bank Limited were account operations and inquiries, fund transfers and payments, utility bill payments, deposits, loans, session summary etc.

Bank Asia: Bank Asia centralized Database with online ATM, SMS and Internet query service. The significant delivery channel of Bank Asia was the shared ATM Network. Bank Asia had 21 ATMs as a member of ETN along with eleven other banks. Bank Asia was maintaining its competitiveness by leveraging on its Online Banking Software and modern IT infrastructure. It was the pioneer amongst the local banks in introducing innovative products like SMS banking, and under the ATM Network the Stellar Online Banking software enables direct linking of a client's account.

BRAC bank: BRAC bank used the most advanced commercially available Secure Socket Layer (SSL) encryption technology to ensure that the information exchange between the customer's Computer and BRACBank.com over the internet was secure and cannot be accessed by any third party.

Arab Bangladesh bank Ltd: Arab Bangladesh bank Ltd was the first private bank of Bangladesh with a long standing experience in domestic and international banking. Its 153 branches in all the major commercial centers of the country and 152 correspondents worldwide provided proficient banking services to its customers.

Prospects of e-banking in Bangladesh

The Bangladesh railway owned a high-speed optical fiber network (1,800 km) parallel to the railway path that covered most of the important parts of Bangladesh. This optical fiber network can be used as the backbone network of e-banking in Bangladesh. For example, mobile phone operators such as Grameen Phone and Ranks ITT of Bangladesh used this optical fiber network through which they reached even in rural areas with their services (Islam 2005). It is encouraging that some of the FCBs and PCBs are already used this optical fiber network for conducting online transactions, ATM and POS services.

In addition, Bangladesh Bank was implementing the different projects for modernizing national payment and settlement system started from 2009 followed by the development of inter-bank online network. It made mandatory for all head offices of the scheduled banks to be connected with Bangladesh Bank. These efforts would allow the scheduled banks to be connected to each other for conducting inter-bank online transactions in near future and this would smooth the introduction of e banking in Bangladesh.

Internet services came to Bangladesh with connectivity in 1996. Digital telephone exchanges established in 389 upazilas and 17 growth centres. Work was underway to cover the rest of the upazilas under digital exchange system. Meanwhile, Bangladesh joined the information super-highway by connecting itself with international submarine cable system in 2006. A total of 159 Internet Service Providers (ISPs) now connected with this system of which 64 are actively providing services. Internet connection was slow with bandwidth range 32 - 56 kbps for dial up and 64 - 8 mbps for broadband. Under this scenario, as a part of government decision of building digital Bangladesh, the existing capabilities of ICT sector was likely to increase rapidly in bringing all upazilas under internet services and this will contribute in widening the scope of e-banking throughout the country.

The overall computer density in the banking sector was 1.64. For foreign commercial banks (FCBs) the computer density was 45.34, where as for NCBs the ratio was only 0.41. The specialized bank scenario was almost same as the NCBs, 0.43. On the other hand, private commercial banks had comparatively higher ratio, 4.94. As a whole 81.81 percent bank did not have any local area network (LAN), 30 percent had WAN (Wide Area Network) but for some banks many branches were outside of WAN connectivity. At present, all foreign banks of our country were using online banking system; they were invested a lot for their automation banking services. For this reason, they were increasing market share every year. They were the pioneer of implementing electronic banking systems in Bangladesh, but now most of the private banks of our country used electronic banking systems. In our country different banks were offering electronic banking services in different ways, some were offering ATM (Automatic Teller Machine) services, some were tele-banking and some were electronic fund transfer, debit card, credit card etc.

Recently, the government's emphasis on building a digital Bangladesh, setting up ICT park, raising allocation for developing ICT infrastructure, waiving taxes on computer peripherals and other measures including the automation program of banking sector led by the Bangladesh Bank and competition among the scheduled banks in improving customer services accelerated the prospects of e-banking in Bangladesh.

Advantages of e-banking in Bangladesh

There were a substantial number of educated unemployed youth forces, with ability to read and write English exist in the country. They trained within a required skill in a short time.

Short term benefits

Reduce extra time; Increase productivity and efficiency; Eliminate duplication and wastage; Cut down maintenance, and shortage cost; Curtail security cost.

Long-term benefits

Create new opportunities of jobs for jobless; participate in the country's economic health; proper planning and monitoring; Proper use resources.

Job creation

According to Bangladesh Bureau of Statistics, the number of unemployed people in Bangladesh in 1990 - 2001 was 1.0 million. Among them 0.2 million are male and 0.8 million female, at the rate of unemployment was 1.1 which was extended 1.9. The issue of computers eliminating jobs of people was quite emotional and painfully real. But it has two sides that automation will eliminate certain types of job like record keeper and also created jobs like administrator, system analyst, programmer, operator etc. and helped to reduce unemployment problem.

Contribution to GDP

Banks with a national economy, work towards building national capital, increasing national savings and mobilizing investments in trade and industry.

Benefits from the banks' point of view

From the banks' view point, the first benefits for the banks offering e-banking services was better branding and better responsiveness to the market. The other benefits were possible to measure in monetary terms. The main goal of every company was to maximize profits for its owners and banks were not any exception. Automated e-banking services offered a perfect opportunity for maximizing profits.

Benefits from the customers' point of view

The main benefit from the bank customers' point of view was significant saving of time by the automation of banking services processing and introduction of an easy maintenance tools for managing customer's money. The main benefits of e-banking were as follows:

Increased comfort and timesaving-transactions made 24 h a day, without requiring the physical interaction with the bank. Quick and continuous access to information. Corporations had easier access to information as, they checked on multiple accounts at the click of a button.

Better cash management. E-banking facilities speed up cash cycle and increases efficiency of business processes as large variety of cash management instruments is available on Internet sites of banks.

Private customers looked for slightly different kind of benefits from e-banking.

Reduced costs: This was in terms of the cost of availing and using the various banking products and services.
Convenience: All the banking transactions performed from the comfort of the home or office or from the place a customer wants to.
Speed: The response of the medium was very fast; therefore customers actually waited till the last minute before concluding a fund transfer.
Fund's management: Customers downloaded their history of different accounts and do a "what-if" analysis on their own PC before affecting any transaction on the web.

Economical benefits

E-banking served so many benefits not only to the bank itself, but also to the society as a whole. E-banking made finance economically possible: (i) Lower operational costs of banks (ii) Automated process (iii) Accelerated credit decisions (iv) Lowered minimum loan size to be profitable.

Potentially lower margins: (i) Lower cost of entry (ii) Expanded financing reach (iii) Increased transparency.

Expand reached through self-service: (i) Lower transaction cost (ii) Make some corporate services economically feasible for society (iii) Make anytime access to accounts and loan information possible.

POLICY IMPLICATIONS

The comprehensive set of e-banking products can help us run our business more effectively by automating many of our critical banking activities and interacting electronically with our bank. Initial cost of e-banking may be high, but it can be recovered within a few years. Electronic banking may play a vital role in order to promote an automated service to the potential customers. Ministry of finance can also play some role for conveyance. Arrange monthly seminar in the banks or in the training academy of the banks to make awareness about the new technology available in banks. Electronic security and viability may require taking faith from the potential clients. Communication should be liberalized for technological advancement. Bank should develop own online software rather depending on other vendors.

LIMITATIONS AND CONSTRAINTS

The focus of the study is mainly based on Dhaka based some selected banks in Bangladesh. E-banking was the important issue in world but Bangladesh is developing country with the limited infrastructure facility and limited skill manpower. Computer literacy was found very few and information technology was in the infant position. There were some limitations faced during the study: Small span on time. Shortage of book and published sources were in Bangladesh. The study was based on limited variable. Difficulties faced to collect the desire information. Disclosing the information was very restricted. IT division was not cooperative all the time. In addition, Interviewing target respondents adopted convenience sampling as alternative to random sampling, at some phases where respondents were inaccessible or not available. Bank officials were found too busy and also reluctant to talk without a proper written permission from the competent authority.

Although e-banking has bright prospects, it involved some financial risks as well. The major risk of e-banking included operational risks (e.g. security risks, system design, implementation and maintenance risks); customer misuse of products and services risks; legal risks (e.g. without proper legal support, money laundering may be influenced); strategic risks; reputation risks (e.g. in case the bank fails to provide secure and trouble free e-banking services, this will cause reputation risk); credit risks; market risks; and liquidity risks.

Conclusions

E-banking, the latest generation of electronic banking transactions, opened up new window of opportunity to the existing banks and financial institutions. Most of the banks have their own websites but not all of them offered internet facilities. The main reason of this was that the banks did not have the IT infrastructure and proper security features. The Ministry of Science, Information and Communication Technology went out the policy for the development in the IT sector.

Another important issue in extending the internet banking services throughout the country was gaining popularity. In Bangladesh most of the people were illiterate and obviously they were technology ignorant. But among the literate portion many of them had computer phobia. So these people could not trust on the internet banking services. To gain the confidence on internet banking the overall computer literacy must be developed. With that goal government had taken initiative even in the root level to develop it literacy in the country. This would be a perfect ground for the development of internet banking.

However, with banking customers growing increasingly comfortable with the digital lifestyle, but Bangladeshi customers were not aware about e-banking in Bangladesh. They were not fully understand the power of technology and seek to leverage it to enjoy better control over their banking operations. To conclude that e-banking also provided other benefits. For instance, creating new markets, and reducing operational costs, administrative costs and workforce are increasingly important aspects for the banks' competitiveness, and e-banking improved these aspects as well. So, Bangladeshi banks should take these advantages of e-banking in Bangladesh economy as early as possible.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support provided by Research University Grant Scheme, No. 101/PJJAUH/811130, Universiti Sains Malaysia, Penang, Malaysia for conducting this research.

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International Journal of the Physical Sciences Vol. 5(7), pp. 931-934, July 2010
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 ©2010 Academic Journals

Full Length Research Paper

Direct solution of Riccati equation arising in inventory production control in a Stochastic manufacturing system

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Accepted 10 June, 2010

We studied the production inventory problem in a manufacturing system with degenerate Stochastic demand. We derived the dynamics of inventory-demand ratio that evolves according to Stochastic neoclassical differential equation through Ito's Lemma. We established the Riccati based solution of the Hamilton- Jacobi-Bellman (HJB) equation associated with this problem.

Key words: Inventory production models, Stochastic differential equations, manufacturing systems.

INTRODUCTION

Many manufacturing enterprises use a production inventory system to manage fluctuations in consumers' demand for the product. Such a system consists of a manufacturing plant and a finished goods warehouse to store those products which are manufactured but not immediately sold. The advantages of having products in inventory are: first they are immediately available to meet demand; second, by using the warehouse to store excess production during low demand periods to be available for sale during high demand periods. This usually permits the use of a smaller manufacturing plant than would otherwise be necessary and also reduces the difficulties of managing the system.

We are concerned with the optimization problem to minimize the expected discounted cost control of production planning in a manufacturing system with degenerate stochastic demand.

$$J(p) = E\left[\int_0^\infty e^{-\rho t}\left\{h(x_t - \bar{x})^2 + c(p_t - \bar{p})^2\right\}dt\right]$$

On simplification if c = h = 1, p¯ = x¯ = 0, then the above production inventory problem becomes:

$$J(p) = E\left[\int_0^\infty e^{-\rho t}\left\{x_t^2 + p_t^2\right\}dt\right] \qquad (1.1)$$

subject to the dynamics of the state equation which says that the inventory at time t is increased by the production rate and decreased by the demand rate can be written as according to

$$dx_t = (p_t - y_t)dt, \quad x_0 = x, \quad x > 0, \qquad (1.2) \qquad (1.2)$$

and the demand equation with the production rate is described by the Brownian motion

$$dy_t = Ay_t + \sigma y_t dw_t, \quad y_0 = y, \quad y > 0 \qquad (1.3)$$

in the class P of admissible controls of production processes pt with non-negative constant $p_t \geq 0$ defined on a complete probability space (Ω, F , P) endowed with the natural filtration Ft generated by σ(ws , s ≤ t) carrying a one-dimensional standard Brownian motion wt , xt is the inventory level for production rate at time t (state variable), yt is the demand rate at time t, pt is the production rate at time t (control variable), ρ > 0 is the constant non-negative discount rate, A is the non-zero constant, σ is non-zero constant diffusion coefficient, x0 is the initial value of inventory level, y0 is the initial value of demand rate, h is the inventory holding cost

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AMS subject classification, 49N05, 60H10, 90B30, 90B05.

coefficient h > 0, c is production cost coefficient c > 0, p^{-} is the value of factory-optimal production level, and x^{-} is the value of factory-optimal inventory level.

The purpose of the paper is to give an optimal production cost control by an existence Riccati solution associated with the reduced (one-dimensional) HJB equation. We first applied the technique of dynamic programming principle (Bellman, 1957) to obtain the general (two-dimensional) HJB equation corresponding to production inventory control problem. We also developed revised optimal inventory-production control problem.

The control problem of production planning in a manufacturing systems with discount rate has been studied by many authors like Fleming et al. (1987), Sethi and Zhang (1994). The Bellman equation associated with production inventory control problem is quite different from them and it is treated by Bensoussan et al. (1984) for the one-dimensional manufacturing systems with the unbounded control region. This type of optimization problem studied also by Morimoto and Kawaguchi (2002) for renewable resources, Baten and Morimoto (2005) for linear degenerate systems, Baten and Sobhan (2007) for one-sector neoclassical growth model with the CES function where the dynamics of the capital-labor ratio can be described by a diffusion-type stochastic process. Generally speaking, the similar types of linear control problems investigated for the stochastic differential systems with invariant measures like Bensossan (1988), Borker (1989).

This paper was organized as follows. In section 2 we obtained the general (two- dimensional) HJB equation by the Bellman principle of optimality and then we reduced the two-dimensional HJB equation to one-dimensional second-order differential equation. Then we derived the dynamics of inventory-demand ratio that evolves according to stochastic neoclassical differential equation through Ito's Lemma. In section we established the Riccati based solution of production inventory control problem that was satisfied by the value function of this optimization problem. Finally conclusions were made in the last section.

MATERIALS AND METHODS

Development of optimal inventory production control problem

The Hamilton-Jacobi-Bellman equation

Suppose u(x, y, t) : Rn × R × Rn → R is a function whose value is the minimum value of the objective function of the production inventory control problem for the manufacturing system given that we start it at time t in state x, and y. That is,

$$u(x,y,t)=\inf_{p} J(p)$$

where the value function u is finite valued and twice continuously differentiable on (0, ∞). We initially assume that the u(x, y, t) exists for all x, y and t in the relevant ranges.

Since (1.2) and (1.3) is a scalar equation, the subscript t here means only time t. Thus, x and y will not cause any confusion and, at the same time, will eliminate the need of writing many parentheses. Thus, dwt is a scalar.

To solve the problem defined by (1.1), (1.2) and (1.3), let u(x, y, t) known as the value function, be the expected value of the objective function (1.1) from t to infinity, when an optimal policy is followed from t to infinity, given xt = x, yt = y. Then by the principle of optimality [Richard Bellman (1957)],

$$u(x,y,t)=\min_{p} E\left[\left\{x_t^2+p_t^2\right\}dt+u\left[x(t+dt),y(t+dt),t+dt\right]\right]+o(dt) \tag{2.1}$$

We assume that u(x, y, t) is a continuously differentiable of its arguments. By Taylor's expansion, we have

$$u\left[x(t+dt),y(t+dt),t+dt\right]=u(x,y,t)-\rho u(x,y,t)dt+u_y dy_t + u_x dx_t+\frac{1}{2}u_{yy}(dy_t)^2+o(dt) \tag{2.2}$$

From (1.2), we can formally write

$$(dx_t)^2=(p_t)^2(dt)^2+(y_t)^2(dt)^2-2p_t y_t (dt)^2 \tag{2.3}$$

$$(dy_t)^2=(Ay_t)^2(dt)^2+(\sigma y_t)^2(dw_t)^2+2(Ay_t)(\sigma y_t)(dt)(dw_t) \tag{2.4}$$

$$dx_t dt = p_t (dt)^2 - y_t (dt)^2 \tag{2.5}$$

and

$$dy_t dt=(Ay_t)(dt)^2+(\sigma y_t)dtdw_t. \tag{2.6}$$

The exact meaning of these expressions comes from the theory of stochastic calculus; Arnold (1974), Karatzas and Shreve (1991). For our purposes, it is sufficient to know the multiplication rules of stochastic calculus

$$(dw_t)^2=dt,\ dw_t dt=0,\ dt^2=0 \tag{2.7}$$

Substitute (2.2) into (2.1) and use (2.3), (2.4) (2.5), (2.6) and (2.7) to obtain

$$u(x,y,t)=\min_{p}\left\{p^2+pu_x\right\}dt+u(x,y,t)-\rho u(x,y,t)dt+\frac{1}{2}\sigma^2y^2u_{yy}dt+ Ayu_y dt-yu_x dt+x^2+o(dt) \tag{2.8}$$

Note that we suppressed the arguments of the functions involved in (2.2).

Canceling the term u on both sides of (2.8), dividing the remainder by dt, and letting t → 0, we obtain the dynamic programming partial differential equation or Hamilton- Jacobi-Bellman equation

$$-\rho u(x,y,t)+\frac{1}{2}\sigma^2y^2u_{yy}+Ayu_y-yu_x+F^{*}(u_x)+x^2=0$$
$$u(0,y)=0,\qquad x,y>0, \tag{2.9}$$

where $F^*(x)$ is the Legendre transform of $F(x)$, that is,

$$F^*(x) = \min_p \{p^2 + px\} = -\frac{x^2}{4}$$

and u_x, u_y, u_{xx}, u_{yy} are partial derivatives of $u(x, y, t)$ with respect to x and y. The main feature of the HJB equation (2.9) is the vanishing of the coefficient of uyy for y = 0 in partial differential equation terminology, then the equation is degenerate elliptic. Generally speaking, the difficulty stems from the degeneracy in the second order term of the HJB equation (2.9).

RESULTS AND DISCUSSION

A reduction to 1-dimensional case

In this subsection, the general (two dimensional) HJB equation reduced to a one-dimensional second-order differential equation. From the two dimensional state space form (one state x for inventory level and the other state y for demand rate) it reduced to one-dimensional form for $(z = x/y)$ the ratio of inventory to demand.

There exists a $v \in (0, \infty)$ such that $u(x, y) = y^2 v(x/y),\ y > 0.$
Since

$$u_x = yv'(x/y)1/y, \quad u_y = 2yv(x/y) - xv'(x/y),$$
$$u_{yy} = 2v(x/y) - 2(x/y)v'(x/y) + (x/y)^2 v''(x/y).$$

Setting z = x/y and substituting these in (2.9), we have

$$-\rho v(z) + \frac{1}{2}\sigma^2\left[2v(z) - 2v'(z)z + z^2 v''(z)\right] + 2Av(z) - Azv'(z) - v'(z) + \min_p \{p^2 + pyv'(z)\} + z^2 = 0 \tag{2.10}$$

Since $\min_p\{p^2 + pyv'(z)\} = y^2 \min_p\{(p/y)^2 + (p/y)v'(z)\} = y^2 \min_q\{q^2 + qv'(z)\}$
and

$$\min_{q \geq 0}\{q^2 + qv'(z) - v'(z)\} = \min_{k+1 \geq 0}\{(k+1)^2 + kv'(z)\}.$$

Then the HJB equation (2.10) became

$$\tilde{\rho}v(z) + \frac{1}{2}\sigma^2 z^2 v''(z) + \tilde{A}zv'(z) + \min_{k+1\geq 0}\{(k+1)^2 + kv'(z)\} + z^2 = 0$$
$$v(0) = 0, \quad z > 0, \tag{2.11}$$

where $\tilde{\rho} = \rho - 2A,\ \text{ and } \tilde{A} = -(A + \sigma^2).$

Stochastic neoclassical differential equation and value function.

In this subsection, the dynamics of the state equation of inventory level (1.2) reduced to a one-dimensional process by working in intensive (per capita) variables.

Define $z_t = x_t/y_t$: inventory-demand ratio and $q_t = p_t/y_t$: per-capita production.

To determine the stochastic differential for the inventory-demand ratio,

$z_t \equiv x_t/y_t$, we apply Ito's formula as follows

$$z = \frac{x}{y} \equiv G(y,t), \quad \text{then } \frac{\partial G}{\partial y} = -\frac{x}{y^2} = -\frac{z}{y}, \quad \frac{\partial^2 G}{\partial y^2} = 2\frac{x}{y^3} = 2\frac{z}{y^2}, \quad \frac{\partial G}{\partial t} = \frac{\dot{x}}{y} = \frac{p}{y} - 1.$$

From Ito's formula,

$$dz = \frac{\partial G}{\partial y}dy + \frac{\partial G}{\partial t}dt + \frac{1}{2}\frac{\partial^2 G}{\partial y^2}(dy)^2. \tag{2.12}$$

From (1.2), we have that (dy) 2 = σ2 y2 dt. Substituting the above expressions into (2.12), we have that the dynamics of zt to be the inventory-demand ratio at time t which evolves according to the stochastic neoclassical differential equation for demand y

$$\begin{aligned} dz_t &= \left(-\frac{z_t}{y_t}\right)(Ay_t dt + \sigma y_t dw_t)(q_t - 1)dt + z_t\sigma^2 dt \\ &= \left[-Az_t + (q_t - 1) + \sigma^2 z_t\right]dt - \sigma z_t dw_t \\ &= \left[(-A + \sigma^2)z_t + (q_t - 1)\right]dt - \sigma z_t dw_t \\ &= [Bz_t + k_t]dt - \sigma z_t dw_t, \quad z_0 = z,\ z > 0, \end{aligned} \tag{2.13}$$

where
$B = -A + \sigma^2, \quad k = q - 1.$

The inventory production control problem became

$$\tilde{J}(k_t) = E\left[\int_0^\infty e^{-\tilde{\rho}t}\{z_t^2 + (k_t + 1)^2\}dt\right] \tag{2.14}$$

subject to degenerate stochastic differential equation

$$dz = [Bz_t + k_t]dt - \sigma z_t dw_t, \quad z_0 = z,\ z > 0. \tag{2.15}$$

Let us consider the minimum value of the payoff function is a function of this initial point. The value function defined as a function whose value is the minimum value of the objective function of the production inventory control problem (2.14) for the manufacturing system, that is,

$$V(z) = \inf_k E\left[\int_0^\infty e^{-\tilde{\rho}t}\{z_t^2 + (k_t + 1)^2\}dt\right] = \inf_k \tilde{J}(k_t) \tag{2.16}$$

The value function V (z) is a solution to the reduced (one dimensional) HJB equation (2.11) and the solution of this HJB equation can be used to test controller for optimality or perhaps to construct a feedback controller. Riccati Based Solution to optimal control problem.

This section finally dealt with the Riccati-based solution of the reduced one-dimensional HJB equation (2.11) corresponding to the production inventory control problem (2.16) subject to (2.13) using the dynamic programmming principle [Richard Bellman, 1957].

To find the Riccati based solution of HJB equation (2.11), we referred to Prato (1984), Prato and Ichikawa (1990) for the degenerate linear control problems related to Riccati equation.

By taking the derivative of (2.11) with respect to k and setting it to zero, we minimized the expression inside the bracket of (2.11).

This procedure built up

$$k_t^{\bullet} = -\left(v'(z)/2\right) - 1. \tag{3.1}$$

Substituting (3.1) into (2.11) yields the equation

$$\tilde{\rho}v(z) + \frac{1}{2}\sigma^2 z^2 v''(z) + Bzv'(z) - \{v'(z)\}^2/4 - v'(z) + z^2 = 0 \tag{3.2}$$

known as the HJB equation. This is a partial differential equation which has a solution form

$$v(z) = az^2(t). \tag{3.3}$$

Then

$$v'(z) = 2az(t), \quad v''(z) = 2a. \tag{3.4}$$

Substituting (3.3) and (3.4) into (3.2) yields

$$\left(1 - \tilde{\rho}a + \sigma^2 a - a^2 + 2aB\right)z^2 - 2az = 0 \tag{3.5}$$

Since (3.5) must hold for any value of z, we must have

$$a^2 - a\left(2B + \sigma^2 + \tilde{\rho}\right) - 1 = 0,$$

is called a Riccati equation from which we obtain

$$a = -\left(2B + \sigma^2 + \tilde{\rho}\right) \pm \sqrt{\left(2B + \sigma^2 + \tilde{\rho}\right)^2 + 4}\Big/2 = K_1 \text{ (constant)}$$

So, (3.3) is a solution form of (3.2).

Conclusion

In general we can further study a stochastic optimal inventory production control problem for linear degenerate systems to minimize the discounted expected cost:

$$J(p) = E\left[\int_0^{\infty} e^{-\rho t}\left\{h(x_t) + p_t^{m}\right\}dt\right]$$

over p ∈P subject to (1.2), (1.3) and (1.4) and in addition a continuous, non-negative, convex function h ∈ R satisfying the polynomial growth condition such that

$$0 \le h(x) \le K\left(1 + |x|^m\right), x \in \Re, m \in \mathrm{N}_+$$

for some constant $K > 0$.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support provided by Research University Grant, No. 1001/PJJAUH/811130, Universiti Sains Malaysia, Penang, Malaysia for conducting this research.

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African Journal of Business Management Vol.5 (3), pp. XXX-XXX, July, 2011
Available online at http://www.academicjournals.org/AJBM
ISSN 1993-8233©2011 Academic Journals

Full Length Research Paper

Measuring Dhaka stock exchange market efficiency: A stochastic frontier analysis

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Accepted 26 May, 2011

This study attempted to measure the status of technical efficiency of companies in Dhaka stock exchange (DSE) for panel data using the stochastic frontier production function, incorporating technical inefficiency effect model. For this study, we used the data collected from DSE market consisting 94 companies in Bangladesh for the period of 2000 to 2008. It was observed that the inefficiency increased over the reference period and translog production function was more preferable than Cobb-Douglas production function. This study showed that the estimated year-wise average efficiency of companies in DSE market was 0.8782 while group-wise average efficiency was 0.8571. At the company group level, Group-A companies was most efficient than the other two groups. The most efficient company was ICB and the most inefficient company was Bextex limited.

Key words: Stochastic frontier model, translog production, stock market efficiency, Dhaka stock exchange, panel data.

INTRODUCTION

Recently, Dhaka stock exchange has taken significant steps towards the development of its capital market. It is the main stock exchange of Bangladesh so we concentrated on the DSE, which is the country's oldest stock exchange, and according to Standard and Poor (2000), the DSE is one of the frontier emerging markets of South Asia. By improving the technical efficiency of DSE market, it can play the desired role in the process of economic development of the country. In DSE, several studies have been conducted for market efficiency. Alam et al. (1999) studied the market efficiency of the DSE. Mobarek et al. (2000) sought evidence supporting existence of at least weak-form efficiency of DSE. Chowdhury et al. (2001) investigated the mean daily returns of DSE around the turn of the week, turn of the month, turn of the year, and around the holidays. A study by Ahmed (2002) revealed that the behavior of stock prices could not be described as obeying the random walk theory rather they follow some dependencies.

Hassan and Maroney (2004) examined the issue of nonlinearity and thin trading as a test for market efficiency in the context of Bangladesh. Stock market economy is currently progressing rapidly due to the economical boost on South Asian region (Mursalin et al., 2006). Uddin and Alam (2007) examined the linear relationship between share price and interest rate, share price and growth of interest rate, growth of share price and interest rate, and growth of share price and growth of interest rate were determined through ordinary least square (OLS) regression. Uddin and Yasmin (2008) sought evidence supporting the existence of market efficiency in the DSE market.

Researchers investigated technical efficiency of financial institutions used either methods, parametric Stochastic frontier approach (SFA) or non-parametric Data envelopment analysis (DEA) in abroad (Berger and Humphrey, 1997). There have been a number of studies, which have compared parametric and non-parametric techniques to examine efficiency of financial institutions, for example, for banking industry (Ferrier and Lovell, 1990; Pastor et al., 1997; Resti, 1997; Bauer et al., 1998; Berger et al., 2000; Altunbas et al., 2001; Maudos et al.,

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2002; Weill, 2004); for the insurance industry (Fecher et al., 1993; Cummins and Zi, 1998). There seems to be no literature on the topics of measuring stock market efficiency of the companies listed in the DSE market in Bangladesh using DEA or SFA approach. It encouraged us to conduct the study to contribute to finance literature and motivates us to undertake this study to fill the gap. In this study we considered the Stochastic frontier approach to measure the technical efficiencies of selected companies in DSE market instead of DEA approach; because of the advantage of SFA which allows a firm to be off the frontier because of random noise and for the main disadvantage of DEA which does not impose any assumptions about production functional form and does not take into account random error, hence the efficiency estimates may be bias if the production process is largely characterized by stochastic elements (Kasman and Turgutlu, 2007).

The stochastic frontier production function was independently proposed in Aigner et al. (1977) and Meeusen and van den Broeck (1977), there has been considerable research to extend and apply the model. Reviews of much of this research are provided in Forsund et al. (1980), Schmidt (1986), Bauer (1990), Battese (1992), and Krikley et al. (1995). In this paper, we used the stochastic frontier production function model specified by Battese and Coelli (1995) for the panel data. The objective of this study is to apply the stochastic frontier production function to investigate the technical efficiencies of companies listed in the Dhaka stock exchange market of Bangladesh. The main focus of our study is to measure the company's technical efficiency in accordance with three groups: Groups A, B and Z and to identify the factors causing technical inefficiency of the stock market.

DHAKA STOCK EXCHANGE (DSE): A BRIEF DESCRIPTION

The Dhaka stock exchange (DSE) was first incorporated as the East Pakistan stock exchange association limited on April 28, 1954. It was renamed as Dhaka stock exchange limited on June 23, 1962.

After the liberation of the country, until 1976, the trading activities of the stock exchange remained closed due to the liberation war and the economic policy pursued by the government. The Securities and Exchange Commission (SEC) which is the regulator of the capital market of Bangladesh was established on 8 June, 1993 under the Securities and Exchange Commission Act, 1993. On August 10, 1998, DSE introduced screen-based state-of-the-art automated online real-time trading through Local area network (LAN) and Wide area network (WAN) on January 24, 2004. Later, the DSE upgraded its automated trading system on August 21, 2005 (Report on Dhaka Stock Exchange" School of Business, University of Information Technology and Sciences, Dhaka, Bangladesh).

There are four markets in the system: (1) public market: Only for market lot share; (2) spot market: Only for spot transactions which must be settled within 24 h; (3) block market: Only for bulk quantities of shares; (4) odd lot market: Only for odd lot scripts. In the public and spot market, securities are traded through automatic matching and block market and odd lot market is traded through pick and fill basis. All transactions are done by the software called TESA. There are three indices in the DSE as follows: (1) DSI index (comprises all listed securities of the exchange), (2) DSE general index (comprises all companies excluding the Z-category companies) and (3) DSE20 index (comprises leading 20 shares with a base index of 1000).

DSE classified the shares in four groups, such as A, B, Z, and N. Group A companies do regular annual general meeting (AGM) and provide dividend minimum which is 10% of EPS. On the other hand, group B companies do regular AGM but provide dividend less than 10% of EPS. Z group companies are irregular in terms of dividend paying and AGM and N (new) groups companies are newly listed companies placed in this category and their settlement system is like B-category companies. The number of listed securities including debentures and bonds in the DSE market is 444 as of 10 December, 2010. In 444 listed securities, there are 217-A category, 11-B category, 7- N category, 15-Z category companies and 8-Debentures, 186-Bonds in the stock exchange market (DSE website: www.dsebd.org; and SEC website: www.secbd.org).

MATERIALS AND METHODS

Stochastic frontier model

Technical efficiency measurement by frontier method is based on the assumption that a gap normally exists between a firm's actual and potential levels of technical performance. Thus, the technical efficiency is measured as the ratio between actual output and the potential output. In stochastic frontier analysis, the assumption is that the production function of the fully efficient firm is known. Lovell et al. (1993) have shown that econometric approaches like the stochastic frontier analysis can distinguish the effects of noise from the effects of inefficiency.

Since one of the objectives of this research is to examine the production efficiency (scores) of listed companies in DSE market, the stochastic frontier analysis was selected as the tool to measure efficiency in this study. So, we considered the stochastic frontier model introduced by Battese and Coelli (1995) for panel data which can be written as:

$$Y_{it} = \beta X_{it} + (V_{it} - U_{it}), \quad i = 1,2,........., N \quad t = 1,2,......., T ....(1)$$

Where, Y_{it} denotes the logarithm of output for the i-th company in the t-th time period; X_{it} denotes the vector of input quantities; β is a vector of unknown parameters to be estimated; V_{it}'s are the error components of random disturbances, distributed i.i.d. $N(0, \sigma_v^2)$ and independent from U_{it}. U_{it}'s are non-negative random variables associated with the technical inefficiency of production and to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution; where $U_{it} = Z_{it}\delta$, where Z_{it} is a (1×p) vector of variables which may influence the inefficiency of companies and δ is a (p×1) vector of parameters to be estimated. The parameterization from Battese and Corra (1977) are used replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and the parameters are estimated by Maximum Likelihood approach.

The Technical inefficiency effect U_{it} in the stochastic frontier model is specified as follows:

$$U_{it} = Z_{it}\delta + W_{it} \quad ....(2),$$

where the random variable, W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_{it}\delta$. Parameters of the stochastic frontier, given by equation (1) and inefficiency model given by equation (2) are simultaneously estimated using maximum likelihood estimation. After obtaining the estimates of U_{it} the profit efficiency of i-th company at t-th time period is given by:

$$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) ....(3)$$

Data sources and variables construction

Data set

The data collected from Dhaka stock exchange (DSE) market consists of 94 companies in Bangladesh for the period of 2000 to 2008. In DSE market, 22 types of category of company exist and this study covered 14 types of category of company as: Banks, Financial Institutions, Mutual Funds, Engineering, Food and Allied Products, Fuel and Power, Textile, Pharmaceuticals and Chemicals, Service and Real Estate, Cement, Tannery Industries, Ceramic Industry, Insurance and Miscellaneous. Out of 94 companies, the data represents both financial and non financial company. In this study, 58 companies are from non financial sector and 36 companies are from financial sector. The data also covered 3 out of 4 groups in DSE market. There are 76 companies belonging to Group-A, 15 companies to Group-B and 3 companies to Group-Z. In short, we can say that, the data represents the overall market.

Dependent variable

i. Individual return (Y): In this study, we took individual company's return as a dependent variable. DSE prepares individual company's daily closing price. Using the closing price of individual company, we calculate the return of individual company as follows:

Individual company's return = ln (P_t) –ln (P_{t-1})

where P_t = closing price at period t; P_{t-1}= closing price at period t-1 and ln = natural log.

In order to obtain the individual company's return, we do not adjust company's dividend, bonus and right issues since many researchers confirmed that their conclusions remained unchanged whether they adjusted their data for dividend, bonus and right issues or not (Lakonishok and Smidt, 1988; Fishe et al., 1993). The reasons to take logarithm returns are justified theoretically and empirically. Theoretically, logarithmic returns are analytically more tractable when linking returns over longer intervals. Empirically, logarithmic returns are more likely to be normally distributed which is a prior condition of standard statistical techniques (Strong, 1992).

Independent variables

i. Market return (X_1): DSE prepares daily price index from daily weighted-average price of daily transaction of each stock. The name of the index is "All share price index". Market return is calculated as follows:

Market return = ln (P_t) –ln (P_{t-1})

where P_t = price index at period t; P_{t-1}= price index at period t-1 and ln = natural log.

ii. Market capitalization(X_2): Market capitalization is the total value of a company's issued share capital as determined by its share price in the stock market. It is calculated as the number of ordinary shares in issue multiplied by the previous day's closing share price and is expressed in millions. The formula is given thus:

Market capitalization = (Previous day's closing share price * Shares in issue).

iii. Book to market ratio (X_3): The book value of a company is total assets minus intangible assets and liabilities. Here we took the company's net asset value per share as a book value of that company. The market value is the share value in the current market price. After establishing the book value and the market value of a company, simply dividing the book value by the market value, we got the book to market ratio as:

Book to market ratio = (Book value/Market value).

iv. Market value (X_4): The total money value of securities traded in a specific period is called the market value of that period. We calculated the market value by multiplying share price by the number of securities traded as:

Market value = (Share price * number of securities traded).

Explanatory variables

i. Time (Z_1): Time is used in this study as influencing variable. A, B and Z are company group specific dummies for Group-A, Group-B and Group-Z respectively. The dummy variables can take either 1 or 0, depending on data availability or not respectively.

Specification of the stochastic frontier translog model and technical inefficiency effects model

In order to select the best specification for the production function (Cobb-Douglas or Translog) for the given data set, we conducted hypothesis tests for the parameters of the stochastic frontier production model using the generalized likelihood - Ratio (LR) statistic defined by:

$$\lambda = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where $\{\ln[L(H_0)]\}$ and $\{\ln[L(H_1)]\}$ are the values of the log-likelihood function for the frontier model under the null and alternative hypotheses. The values of the log likelihood for the Cobb-Douglas and Translog production frontiers are -132.9089 and -74.7714, respectively. By employing equation (4), we estimated the values of Likelihood ratio (LR) statistic $\lambda = 116.2750 (Table\ 7)$. This value was compared with the critical value of Kodde and Palm (1986) table. Finally it concluded that the null hypothesis $H_0 : \beta_{ij} = 0$ was strongly rejected and it indicated that Translog production function was found more preferable than Cobb-Douglas production function. Thus we can write the model as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln MR_{it} + \beta_2 \ln MC_{it} + \beta_3 \ln BM_{it} + \beta_4 \ln MV_{it} + 1/2(\beta_{11} \ln MR_{it}^2 + \beta_{22} \ln MC_{it}^2 + \beta_{33} \ln BM_{it}^2 + \beta_{44} \ln MV_{it}^2) + \beta_{12} \ln MR_{it} * \ln MC_{it} + \beta_{13} \ln MR_{it} * \ln BM_{it} + \beta_{14} \ln MR_{it} * \ln MV_{it} + \beta_{23} \ln MC_{it} * \ln BM_{it} + \beta_{24} \ln MC_{it} * \ln MV_{it} + \beta_{34} \ln BM_{it} * \ln MV_{it} + V_{it} - U_{it} \ldots\ldots\ldots\ldots (5)$$

where, the subscripts i and t represent the i-th company and the t-th year of observation, respectively; $i=1,2,\ldots,94$; $t=1,2,\ldots,9$; Y_{it} represents the individual return of the i-th company in the t-th period; MR_{it} represents the market return of the i-th company in the t-th period; MC_{it} represents market capitalization of the i-th company in the t-th period; BM_{it} represents book to market ratio of the i-th company in the t-th period; MV_{it} represents market value of the i-th company in the t-th period. "ln" refers to the natural logarithm; the β_i's are unknown parameters to be estimated; V_{it} follows $N(0, \sigma_v^2)$ and U_{it} follows a truncations at zero of the $N(\mu, \sigma_u^2)$ distribution.

Further, the company specific inefficiency is considered as a function of some explanatory variables and the inefficiency effects model is defined as:

$$U_{it} = \delta_0 + \delta_1 T + \delta_2 A + \delta_3 B + \delta_4 Z + W_{it} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where δ_0 is the intercept term and $\delta_j (j = 1,2,3,4)$ is the parameter for the j-th explanatory variable, T =Year of observation, A is the dummy variable for Group-A companies; A=1 if an observation involves the Group-A, zero otherwise; B is the dummy variable for Group-B companies: B =1 if an observation involves the Group-B, zero otherwise; Z is the dummy variable for Group-Z companies: Z =1 if an observation involves the Group-Z, zero otherwise.

Tests of hypothesis

The hypothesis tests are obtained using the generalized likelihood-ratio test statistic (4). This test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Taymaz and Saatci, 1997). These are obtained by using the values of the log–likelihood functions for the companies and the stochastic frontier production function.

$H_0 : \gamma = 0$, the null hypothesis specifies that the technical inefficiency effects in companies are zero. This is rejected in favor of the presence of inefficiency effects. Here γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiency and defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier models by using the computer program frontier version 4.1 developed by Coelli (1996). If the null hypothesis is accepted, this would indicate that σ_u^2 is zero and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square (OLS). Further, $H_0 : \eta = 0$, the null hypothesis that the technical inefficiency effects are time invariant, that is, there is no change in the technical inefficiency effects over time. If the null hypothesis is true, the generalized likelihood ratio statistic λ is asymptotically distributed as a chi-square (or mixed chi-square) random variable.

RESULTS AND DISCUSSION

Here, maximum likelihood estimates (MLE) of the parameters were reported in the context of company specific efficiency of Dhaka stock exchange followed by translog stochastic frontier model. The MLE of parameters in the model are shown in the Table 1. The results showed that the maximum-likelihood estimates of the coefficients of market return, market capitalization, book to market ratio and market value were found significant at 1% level of significance. The square effects and interaction effects of the input variables-market return, market capitalization, book to market ratio and market value were also statistically significant at different level of significance. The estimates of the parameters of the inefficiency effects model were reported in the Table 2. In the inefficiency effects model, a positive coefficient

Table 1. Maximum-likelihood estimates of translog stochastic frontier production model.

Variables	Parameters	Coefficients	S.E	t-value
Constant	β_0	-36.3802**	15.1829	-2.3961
Market return	β_1	3285.9946*	1.9843	1655.9823
Market capitalization	β_2	-15086.0080*	0.9008	-16745.6390
Book to market ratio	β_3	-3092.0590*	0.9003	-3434.3754
Market value	β_4	9973.9074*	0.9044	11028.0030
Market return * Market return	β_{11}	-1675.2537*	3.6459	-459.4883
Market capitalization*Market capitalization	β_{22}	7543.3792*	0.4905	15376.3640
Book to market ratio * Book to market ratio	β_{33}	1546.3670*	0.4914	3146.2640
Market value * Market value	β_{44}	-4985.5428*	0.5962	-8361.7013
Market return * Market capitalization	β_{12}	6.1555*	0.7802	7.8890
Market return * Book to market ratio	β_{13}	-0.1939*	0.0703	-2.7561
Market return * Market value	β_{14}	-4.8864*	0.5884	-8.3039
Market capitalization * Book to market ratio	β_{23}	-0.1287*	0.0491	-2.6195
Market capitalization * Market value	β_{24}	-0.0745**	0.0314	-2.3710
Book to market ratio * Market value	β_{34}	0.1344*	0.0448	3.0019

*, **, *** Significance level at 1, 5 and 10% consecutively; @ means insignificant, S.E = Standard error.

Table 2. Maximum likelihood estimates of the parameters of inefficiency effects model.

Variables	Parameters	Coefficients	S.E	t-value
Constant	δ_0	-3.6234*	0.9906	-3.6575
Time	δ_1	0.5058*	0.0977	5.1735
Group-A Dummy	δ_2	-1.5847*	0.6037	-2.6246
Group-B Dummy	δ_3	-1.2596**	0.5856	-2.1509
Group-Z Dummy	δ_4	-0.7790@	0.5701	-1.3663
Sigma-squared	σ^2	0.3784*	0.0706	5.3578
Gamma	γ	0.8643*	0.0296	29.1480
Loglikelihood function		-74.7714		

*, **, *** Significance level at 1, 5 and 10% consecutively; @ means insignificant, S.E = Standard error.

value increased the level of inefficiency and vice-versa. Hence from the result, it was reported that Groups -A and -B companies were found decreasing the level of inefficiency. These indicated that the Groups -A and -B companies were inversely related with inefficiency. There was no significant effect of Group-Z companies though it was negative. Other explanatory variable in the inefficiency model was "Time". The positive coefficient of time indicated that the technical efficiency level tended to decrease by 50.58% per year over the time period 2000 to 2008. The value of γ was estimated at 0.8643 which was positive and significant at 1% level of significance. It could be interpreted as follows: 86% of random variation around in stock market returns due to inefficiency and 14% due to stochastic random error. This could be interpreted that 86% variations in output among the companies were due to the differences in technical efficiency. It is evident from Table 2 that, the estimate of σ was 0.3784 which was significantly different from zero, indicated a good fit. The year wise mean efficiency of 94 companies in DSE market is displayed in Table 3. From this investigation, we observed that the highest mean efficiency was in 2000 and the score was 93.60% and the lowest mean efficiency was in 2008 and the score was 75.68%. In 2008, the mean efficiency decreased by 19.15 from 2000. Time was observed as an important affect in increasing inefficiency. It was also revealed from Table 3 that the mean technical efficiency of the companies of

Table 3. Year wise mean efficiency of companies in Dhaka stock exchange.

Year	Mean
2000	0.9360
2001	0.9275
2002	0.9167
2003	0.9140
2004	0.8942
2005	0.8836
2006	0.8588
2007	0.8162
2008	0.7568
Mean	0.8782

Table 4. Group wise mean efficiency of companies in Dhaka stock exchange.

Year	Group-A	Group-B	Group-Z
2000	0.9396	0.9223	0.9117
2001	0.9326	0.9212	0.8283
2002	0.9163	0.9239	0.8894
2003	0.9176	0.9064	0.8594
2004	0.9063	0.8661	0.7282
2005	0.8894	0.8767	0.7706
2006	0.8537	0.8808	0.8771
2007	0.8261	0.7709	0.7903
2008	0.7647	0.7174	0.7536
Mean	0.8829	0.8651	0.8232

DSE market during the period 2000 to 2008 was found to be 0.8782. This implied that 87% of potential output was being realized by the companies of DSE market. The group wise mean efficiency of 94 companies in DSE market is displayed in Table 4. It was observed that in case of higher efficiency, the Group-A companies were most efficient (88.29%). These findings are in line with the argument that the companies included in Group-A were found to be superior as they were regular in holding the annual general meetings and declared dividend at the rate of 10% or more in a calendar year.

The Group-B (86.51%) and the Group-Z (82.32%) companies were relatively less efficient than Group-A companies because the companies included in Group-B were regular in holding the annual general meetings (AGM) but failed to declare dividend at least at the rate of 10% in a calendar year and the companies included in Group-Z were also failed to hold the annual general meetings or failed to declare any dividend. But during the period 2000 to 2008, the efficiency of Group-A companies (91.63%) was lower than Group-B companies (92.39%) in the year 2002 and also the efficiency of Group-A companies (85.37%) was lower than Group-B (88.08%) and Group-Z (87.71%) companies in the year 2006.The rest of the years in the study period the companies included in Group-A showed higher efficiency than the other two groups. Company's year-wise technical efficiency in DSE market showed a more clear perception about the performance of an individual company was displayed in Table 5. There was a variation in the technical efficiencies among the different companies in DSE market: it ranged from a low of 0.7650 for company Bextex Limited, to a high of 0.9219 for company ICB.

The actual range in this case was found to be 0.1569. The most efficient companies during the study period were found to be ICB (with 92.19%), Apex Adelchy Footwear (92.01%), ACI Limited (91.67 %), 7th ICB M.F. (91.28 %), and 1st BSRS (91.14%). On the contrary, the most inefficient companies during the data period were Bextex Limited (76.05%), Al-Arafah Islami Bank (78.90%), Aramit Cement (81.39%), Anwar Galvanizing (82.70%) and BD.Autocars (with 82.87%). From the investigation, it was observed that the top five companies are Group-A companies and among the bottom five companies there were three Group-Z companies.

Table 5. Company's year-wise efficiency in Dhaka stock exchange market.

Firm's name	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean efficiency
AB Bank	0.9464	0.9605	0.9422	0.8922	0.8970	0.9218	0.9506	0.9425	0.6059	0.8955
City Bank	0.9396	0.9573	0.9476	0.9008	0.9488	0.9028	0.8719	0.7557	0.4763	0.8557
IFIC Bank	0.9491	0.9649	0.8989	0.9207	0.9062	0.9349	0.9487	0.9285	0.5121	0.8849
Islami Bank	0.9476	0.9317	0.9403	0.9106	0.9013	0.9211	0.8823	0.7093	0.6473	0.8657
NBL	0.9662	0.9607	0.9288	0.9041	0.9196	0.9474	0.9300	0.8334	0.5759	0.8851
Uttara Bank	0.9479	0.9724	0.9519	0.9374	0.9517	0.9442	0.8876	0.8354	0.6125	0.8934
Eastern Bank	0.9510	0.9604	0.9423	0.9240	0.9137	0.9391	0.8973	0.7318	0.5260	0.8651
Al-Arafah IB	0.9431	0.9376	0.9248	0.9288	0.9221	0.9161	0.8800	0.4787	0.1697	0.7890
ICB	0.9137	0.9145	0.9431	0.8919	0.9181	0.9265	0.8848	0.9607	0.9441	0.9219
IDLC	0.9433	0.9260	0.9390	0.9176	0.9130	0.9047	0.8776	0.7966	0.8482	0.8962
United Leas.	0.9391	0.9234	0.9400	0.9345	0.9151	0.8605	0.7321	0.6908	0.6856	0.8468
Uttara Finan.	0.9454	0.9424	0.9451	0.9348	0.9217	0.9204	0.7893	0.7866	0.6559	0.8713
1stICB M.F.	0.9448	0.9384	0.9206	0.9176	0.8848	0.8982	0.9069	0.8607	0.7688	0.8934
2nd ICB M.F	0.9260	0.9331	0.9267	0.9229	0.8947	0.9174	0.9006	0.8827	0.8435	0.9053
3rd ICB M.F.	0.9370	0.9372	0.9298	0.9207	0.8831	0.8900	0.8555	0.8569	0.8038	0.8905
4th ICB M.F.	0.9450	0.9322	0.9230	0.9125	0.8870	0.9056	0.8913	0.8685	0.8215	0.8985
5th ICB M.F.	0.9398	0.9307	0.9247	0.9173	0.8886	0.8990	0.8823	0.9147	0.8957	0.9103
6th ICB M.F.	0.9334	0.9351	0.9272	0.9110	0.8839	0.8998	0.8886	0.9013	0.8384	0.9021
7th ICB M.F.	0.9434	0.9355	0.9234	0.9097	0.8949	0.9127	0.8799	0.9146	0.9008	0.9128
8th ICB M.F.	0.9412	0.9377	0.9289	0.9112	0.8944	0.9094	0.8864	0.8977	0.8474	0.9060
1st BSRS	0.9359	0.9465	0.9416	0.9055	0.8818	0.8990	0.8807	0.9649	0.8466	0.9114
Aftab Aoto.	0.9492	0.9283	0.9388	0.9319	0.9351	0.8747	0.7958	0.8002	0.6134	0.8631
Olympic Ind.	0.9321	0.9353	0.9116	0.9353	0.9201	0.8867	0.8426	0.8900	0.7830	0.8930
BD. Lamps	0.9392	0.8999	0.9100	0.9216	0.8946	0.9117	0.8671	0.8087	0.7242	0.8752
Eastern Cable	0.9415	0.9403	0.9466	0.9200	0.8812	0.8811	0.9121	0.9348	0.6213	0.8866
Monno Jutex	0.8901	0.9070	0.9217	0.8873	0.9256	0.8941	0.8942	0.6897	0.7085	0.8576
Monno Stafl.	0.9359	0.9293	0.9278	0.8939	0.8814	0.8894	0.9073	0.6993	0.6383	0.8558
Singer BD.	0.9401	0.9215	0.9259	0.9087	0.7642	0.7977	0.7957	0.8816	0.7087	0.8493
Atlas BD.	0.9375	0.9239	0.9433	0.9297	0.9038	0.8914	0.7999	0.8640	0.5648	0.8620
BD.Autocars	0.8517	0.6319	0.9450	0.9422	0.7754	0.7811	0.9144	0.7951	0.8212	0.8287
Quasem Dry.	0.9301	0.9393	0.9247	0.8946	0.8955	0.8937	0.8526	0.8502	0.8904	0.8968
National Tub.	0.9444	0.9203	0.9205	0.9155	0.9590	0.9003	0.7227	0.8560	0.7040	0.8714
Bd.Thai Alum.	0.9439	0.8624	0.9233	0.9035	0.8475	0.8512	0.7371	0.7297	0.9372	0.8595
Anwar Gal.	0.9227	0.9183	0.9167	0.8772	0.8022	0.7885	0.8155	0.7371	0.6651	0.8270
Kay and Que	0.8976	0.9411	0.9447	0.9155	0.8228	0.8085	0.8095	0.7088	0.9051	0.8615
National Poly.	0.9483	0.9314	0.9165	0.9053	0.9068	0.9256	0.9469	0.7986	0.8910	0.9078
Apex Foods	0.9383	0.9207	0.9089	0.9327	0.9302	0.9013	0.8714	0.9036	0.7120	0.8910
Bangas	0.9437	0.9402	0.9335	0.9197	0.8808	0.8948	0.8605	0.8026	0.7599	0.8818
BATBC	0.9308	0.9251	0.9096	0.9238	0.8907	0.8264	0.8197	0.8246	0.7962	0.8719
National Tea	0.9393	0.9204	0.9167	0.9075	0.8483	0.8956	0.8211	0.7850	0.8110	0.8716
AMCL (Pran)	0.9519	0.9192	0.9319	0.9190	0.9030	0.8792	0.8742	0.8322	0.8233	0.8926
Rahima Food	0.9220	0.9001	0.9271	0.8906	0.7493	0.8359	0.9550	0.7958	0.6239	0.8444
BOC	0.9430	0.9176	0.9295	0.9309	0.8876	0.8481	0.8819	0.8820	0.7262	0.8830
Padma Oil Co.	0.9259	0.9379	0.9381	0.9489	0.8476	0.9212	0.9378	0.8564	0.7651	0.8977
Saiham Textile	0.9245	0.9159	0.9139	0.9147	0.8976	0.9008	0.8848	0.8455	0.7132	0.8790
Desh Garman.	0.9360	0.8925	0.9357	0.9162	0.8113	0.9018	0.9003	0.7715	0.5094	0.8416
Bextex Ltd.	0.9440	0.8760	0.2759	0.8858	0.9391	0.9268	0.8439	0.6477	0.5048	0.7605
Apex Spinning	0.9399	0.9447	0.9340	0.9281	0.9284	0.9034	0.8707	0.8154	0.8023	0.8963
Delta Spinners	0.9023	0.9372	0.9284	0.9255	0.9385	0.8932	0.9012	0.8202	0.7438	0.8878
Sonargaon Te.	0.9228	0.9279	0.9327	0.9194	0.8684	0.8981	0.8909	0.7094	0.8285	0.8776
Prime Textile	0.9422	0.9527	0.9112	0.8778	0.9151	0.8917	0.8928	0.8573	0.7386	0.8866

Table 5. Contd.

H.R.Textile	0.9381	0.9299	0.8909	0.9032	0.9032	0.8858	0.8994	0.7899	0.7348	0.8750
Ambee Phar.	0.9467	0.9377	0.9166	0.9133	0.8893	0.8967	0.8672	0.7649	0.8795	0.8902
Beximco Phar.	0.9491	0.9359	0.9106	0.8956	0.9354	0.9300	0.8279	0.7733	0.8107	0.8854
Glaxo SmithK.	0.9334	0.9116	0.9359	0.9110	0.9115	0.9003	0.8602	0.7621	0.7755	0.8779
ACI Limited	0.9562	0.9420	0.9280	0.9184	0.9049	0.8951	0.8871	0.8958	0.9229	0.9167
Renata Ltd	0.9374	0.9418	0.9420	0.9393	0.9538	0.9239	0.8886	0.8663	0.7920	0.9094
Reckitt Benc.	0.9259	0.9336	0.9380	0.8888	0.8899	0.8963	0.9365	0.8613	0.7766	0.8941
The Ibn Sina	0.9473	0.9386	0.9414	0.9328	0.9199	0.8921	0.8534	0.7742	0.7718	0.8857
Beximco Syn.	0.9355	0.9319	0.8965	0.8727	0.9248	0.8803	0.8747	0.8347	0.6752	0.8696
Libra Infus.	0.9203	0.9180	0.9415	0.9236	0.9300	0.9076	0.8700	0.7984	0.8238	0.8926
Square Pharma	0.9580	0.9464	0.9212	0.9130	0.9431	0.8827	0.8387	0.8455	0.5968	0.8717
Imam Button	0.9258	0.9300	0.9125	0.8950	0.8617	0.8094	0.8838	0.8241	0.8223	0.8738
Samorita Hos.	0.9367	0.9280	0.9348	0.9190	0.8029	0.8942	0.8961	0.7033	0.6783	0.8548
Eastern Hous.	0.9342	0.9255	0.9022	0.9162	0.9148	0.8801	0.8932	0.8781	0.7707	0.8906
Heidelberg C.	0.9634	0.9120	0.8567	0.8730	0.8967	0.8820	0.8593	0.8937	0.6417	0.8643
Confidence C.	0.9633	0.9325	0.8558	0.8086	0.8680	0.8939	0.9104	0.9349	0.5854	0.8614
Meghna C.	0.9664	0.9473	0.9017	0.8882	0.8891	0.8881	0.8994	0.8042	0.6872	0.8746
Aramit C.	0.9608	0.9346	0.8065	0.7588	0.6070	0.7424	0.9014	0.8389	0.7744	0.8139
Apex Tannery	0.9118	0.9445	0.9303	0.9267	0.9111	0.8986	0.9014	0.9021	0.8547	0.9090
Bata Shoe	0.9405	0.9328	0.9244	0.9244	0.8782	0.8702	0.8461	0.8314	0.8125	0.8845
Apex Adelch.	0.9416	0.9348	0.9196	0.9193	0.9397	0.9238	0.8736	0.9428	0.8854	0.9201
Monno Cer.	0.9255	0.9133	0.9081	0.9144	0.8428	0.8752	0.8408	0.7801	0.6565	0.8507
Standard Cer.	0.9320	0.9249	0.9277	0.9388	0.8857	0.8525	0.8401	0.8110	0.6398	0.8614
BGIC	0.9301	0.9115	0.9200	0.9386	0.9409	0.7891	0.7784	0.8145	0.8789	0.8780
Green D.Ins.	0.9449	0.9234	0.9345	0.9279	0.9298	0.8436	0.7646	0.8384	0.9238	0.8923
United Ins.	0.9371	0.9328	0.9360	0.9397	0.9253	0.8952	0.8974	0.7525	0.8308	0.8941
Peoples Ins.	0.9165	0.9429	0.9187	0.9230	0.9222	0.8721	0.6923	0.5058	0.8689	0.8403
Eastern Ins.	0.9311	0.9300	0.9283	0.9369	0.9287	0.8822	0.8298	0.8123	0.8048	0.8871
Janata Ins	0.9356	0.9099	0.9100	0.9363	0.9178	0.8391	0.7733	0.8058	0.9118	0.8822
Phoenix Ins	0.9350	0.9293	0.9382	0.9309	0.9044	0.8681	0.8076	0.8160	0.7614	0.8768
Eastland Ins	0.9331	0.9303	0.9293	0.9345	0.9397	0.8594	0.8325	0.8571	0.9107	0.9030
Central Ins	0.9334	0.9315	0.9229	0.9236	0.9281	0.8530	0.8059	0.8213	0.8471	0.8852
Karnaphuli Ins	0.9351	0.9374	0.9242	0.9310	0.9187	0.8205	0.8275	0.8370	0.8884	0.8911
Rupali Ins	0.9275	0.9289	0.9145	0.9309	0.9370	0.8816	0.8000	0.8866	0.8793	0.8985
Federal Ins	0.9272	0.9443	0.9113	0.9241	0.9069	0.8666	0.8099	0.8547	0.8789	0.8915
Reliance Ins	0.9443	0.9205	0.9347	0.9404	0.9257	0.8158	0.7439	0.7968	0.8767	0.8776
Purabi G.Ins	0.9399	0.9517	0.8991	0.9260	0.8991	0.8691	0.8029	0.7958	0.8594	0.8826
Pragati Ins.	0.9354	0.9197	0.9412	0.9343	0.8966	0.8388	0.8594	0.7744	0.8814	0.8868
Aramit	0.9404	0.9336	0.9196	0.9234	0.8912	0.9013	0.8814	0.8193	0.9114	0.9024
GQ Ball Pen	0.9261	0.9447	0.9176	0.9274	0.8962	0.8555	0.8394	0.8683	0.7114	0.8763
Usmania Glass	0.9518	0.9535	0.9491	0.9383	0.9373	0.8887	0.7615	0.8842	0.7569	0.8913
Savar Ref.	0.8828	0.9147	0.9467	0.8985	0.8476	0.9035	0.9227	0.6975	0.6069	0.8468
BEXIMCO	0.9343	0.9291	0.8970	0.9029	0.8865	0.9495	0.8191	0.6665	0.9215	0.8785

Results of hypothesis tests

The results of various hypothesis tests for the model are presented in Table 6. The all hypothesis tests were obtained using the generalized likelihood-ratio statistic (4). The second null hypothesis is $H_0: \gamma = 0$, which Specified that there was no technical inefficiency effect in the model. The hypothesis was rejected, so we concluded that there was a technical inefficiency effect in the model. The third null hypothesis is H_0: $\eta = 0$, which specified that the technical inefficiency effect did not vary significantly over time. The null hypothesis was rejected indicating that the technical inefficiency effect varied significantly.

Table 6. Likelihood-ratio test of hypothesis of the stochastic frontier translog model.

Null hypothesis	Log-likelihood function	Test statistic λ	Critical value*	Decision
$H_0 : \beta_{ij} = 0$	-132.9089	116.2750	11.911	Reject H_0
$H_0 : \gamma = 0$	-101.9755	54.4082	11.911	Reject H_0
$H_0 : \eta = 0$	-157.1236	16.0668	5.138	Reject H_0

All critical values are at 5% level of significance. *The critical values are obtained from table of Kodde and Palm (1986). The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution, because the restriction defines a point on the boundary of parameter space.

CONCLUSION

This study focused on the estimation of the technical efficiency of the companies listed in the DSE market applying the stochastic frontier approach. We observed that the variables market return, market capitalization, book to market ratio and market value show significant affects for MLE estimation of the translog production function. These results indicated that these input variables significantly affect the return of individual company of the share market in Bangladesh. From the inefficiency effects model, we found that the variable Groups -A and -B significantly contributed to improve technical efficiency of return in DSE market. The result showed that the explanatory variable "time" has significant impact. It indicated that technical inefficiency increased over the reference period. This means that, the technical efficiency rate was found gradually decreasing over time in the stock market in Bangladesh. According to the results obtained from the stochastic frontier estimation, the mean technical efficiency of DSE market during the period 2000 to 2008 given by the translog model was 0.8782. This implies that 87% of potential yield was being realized by the companies in the market and also indicated that there was a scope to further increase the output by 13 % without increasing the levels of inputs. In this study we also found that the companies which are listed in Group-A were the most efficient companies among the three groups. As a result, this study examined the efficiency and other characteristics of DSE markets which would be of great benefit to investors at home and abroad, policy makers and local and foreign listed and unlisted companies and has important practical implications to different capital market participants. Finally, it may also be useful for international organizations and governments of development partners who are interested in the development of capital markets in the emerging countries.

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Author should provide correct references

APPENDIX

List of companies considered in this study

List of company's name	Serial number	List of company's name	Serial number
AB Bank	1	Apex Spinning	48
City Bank	2	Delta Spinners	49
IFIC Bank	3	Sonargaon Textiles	50
Islami Bank	4	Prime Textile	51
NBL	5	H.R.Textile	52
Uttara Bank	6	Ambee Pharma	53
Eastern Bank	7	Beximco Pharma	54
Al-Arafah IB	8	Glaxo SmithKline	55
ICB	9	ACI Limited	56
IDLC	10	Renata Ltd	57
United Leasing	11	Reckitt Benckiser	58
Uttara Finance	12	The Ibn Sina	59
1stICB M.F.	13	Beximco Synthetics	60
2nd ICB M.F	14	Libra Infusions	61
3rd ICB M.F.	15	Square Pharma	62
4th ICB M.F.	16	Imam Button	63
5th ICB M.F.	17	Samorita Hospital	64
6th ICB M.F.	18	Eastern Housing	65
7th ICB M.F.	19	Heidelberg Cement	66
8th ICB M.F.	20	Confidence Cement	67
1st BSRS	21	Meghna Cement	68
Aftab Automobiles	22	Aramit Cement	69
Olympic Industries	23	Apex Tannery	70
Bangladesh Lamps	24	Bata Shoe	71
Eastern Cables	25	Apex Adelchy Footwear	72
Monno Jutex	26	Monno Ceramic	73
Monno Stafllers	27	Standard Ceramic	74
Singer Bangladesh	28	BGIC	75
Atlas Bangladesh	29	Green D.Ins.	76
BD.Autocars	30	United Ins.	77
Quasem Drycells	31	Peoples Ins.	78
National Tubes	32	Eastern Ins.	79
Bd.Thai Aluminium	33	Janata Ins	80
Anwar Galvanizing	34	Phoenix Ins	81
Kay & Que	35	Eastland Ins	82
National Polymer	36	Central Ins	83
Apex Foods	37	Karnaphuli Ins	84
Bangas	38	Rupali Ins	85
BATBC	39	Federal Ins	86
National Tea	40	Reliance Ins	87
AMCL (Pran)	41	Purabi G.Ins	88
Rahima Food	42	Pragati Ins.	89
BOC	43	Aramit	90
Padma Oil Co.	44	GQ Ball Pen	91
Saiham Textile	45	Usmania Glass	92
Desh Garmants	46	Savar Ref.	93
Bextex Limited	47	BEXIMCO	94

International Journal of the Physical Sciences Vol. 6(11), pp. xxx-xxx, 18 July, 2011
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Wage augmented stochastic frontier model with truncated normal distribution

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Accepted 10 June, 2011

This study considered wage augmented production frontiers with inefficiency effects model proposed by (Battese and Coelli, 1992) where the efficiency wage hypotheses was tested. An unbalanced panel data on 31 manufacturing firm for the period 1989 to 2000 was used in this study. The wage augmented Cobb-Douglas production function was originated to be an unsatisfactory representation of the data compared to wage augmented Translog frontier model. The results showed that the wage level was one of the significant factors contributing to the output and technical efficiency in truncated normal distribution which was found to be of inferior quality in manufacturing industry in Bangladesh.

Key words: Wage augmented production model, inefficiency effect, Cobb-Douglas production model, production model, truncated normal distribution

INTRODUCTION

The manufacturing process may play a vital role in the development process by creating new jobs, increasing exports, and displacing imports. But efficiency is the first condition that has to be achieved to be competitive internationally. In order to accelerate the development process, industries have to be come technically efficient. Without improving its technical efficiency, the manufacturing sector cannot play the desired role in the process of economic development of the country. The way, efficiency analysis is an issue of interest given that the overall productivity of an economic system is directly related to the efficiency of production of the components within the system.

We are concerned with the study of wage level efficiency in manufacturing firm of Bangladesh using stochastic frontier production model since the wage level is a significant factor in determining efficiency at the firm level in the manufacturing firm. However, efficiency wage hypothesis states that work effort depends positively on the wage level.

A number of studies have been done in the context of wage level efficiency (for example Solow, 1979; Shapiro and Stiglitz, 1984, for shirking version; Salop, 1979 for rnover version; Weiss, 1980 for adverse selection version; Akerlof, 1982 for sociological version). In this same context, a few works have been done for the efficiency measurements of firms (e.g. Riveros and Bouton,1994; Saygili,1998; Rogers, 2002; Mahadevan, 2002a; Ogloblin, 2005; Jajri et al., 2006; Brock ND Ogloblin, 2006; Blackaby et al., 2007; Brown and Taylor, 2008; Okoye et al., 2008; Rana et al., 2010) using stochastic frontier analysis. This study is motivated by the informal structure of the industrial wage market in Bangladesh. In order to test the efficiency wage hypothesis, this study was employed both wage augmented Cobb-Douglas and standard Translog production frontiers to measure technical efficiency of industries of firms in Bangladesh. Here the effect of the wage level on a firm's performance is directly tested using (Battese and Collie, 1992) model.

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MATERIALS AND METHODS

The data obtained from the Census of Manufacturing Industries (CMI) is conducted by the Bangladesh Bureau of Statistics (BBS) every year. The study area covered selected 3-digit census factories, under the registered manufacturing sector of Bangladesh over the reference period 1988-1989 to 1999-2000. As data for three years, viz. 1994 to 1995, 1996 to 1997 and 1998 to 1999 were not published; data for the remaining 9 years are considered for this study. The estimates at constant prices (1988 to 1989 = 100) are derived. We have considered 31 industries for each year

Table 1. Summary statistics of output, input and explanatory variables.

Variable	Description	Mean	Std. Deviation	Minimum	Maximum
Y	Gross Output	14.619	2.544	5.332	19.482
X_1	Capital	13.633	2.562	4.779	18.864
X_2	Manual Labor	4.753	.611	1.000	7.086
X_3	Non-Manual Labor	4.807	.614	2.647	7.381
X_4	Wage Rate for Manual Labor	3.913	.583	.500	5.381
X_5	Wage Rate for Non-Manual Labor	3.239	.565	1.465	19.216
X_6	Cost of Raw Materials	14.106	.564	.020	19.216
X_7	Time trend				

N=279

and we have total 279 observations over the nine year time period. The motivation for the choice of this data set is that, to the best of our knowledge, it is the only existing comprehensive firm level data set available in Bangladesh followed by standard input–output classification, Bangladesh Bureau of Statistics. Variables considered in this study including dependent, independent variables are listed in Table 1.

Application of an average production function as well as the stochastic production frontier framework is appropriate to analyze wage efficiency on productivity and efficiency. Cobb-Douglas production frontier and Translog frontier production model were used for the analysis of panel data, using frontier analysis. The model is discussed in this study assuming that the data are available for a sample of N firms over T time periods.

Wage augmented Cobb-Douglas stochastic frontier production model

Assuming a standard log-linear (Cobb-Douglas) production function and taking logs produces the production frontier model in the form proposed by (Lovell et al., 1992):

$$\ln y_{it} = \beta_0 + \sum_{i=1}^{7} \beta_i \ln x_{it} + v_{it} - u_{it} \quad (1)$$

where y_{it} represent the gross output level of the i-th sample industry in t-th time, x_{it} of input variables (capital, manual labor, non-manual labor, wage rate for manual labor, wage rate for non-manual, cost of raw materials and time) the i-th industry in t-th time and a vector, β, $\beta_i\,(i=1,2,\ldots,7)$ stands for the output elasticity with respect to the i-th input. V_{it} s are assumed to be independent and identically distributed random errors which have normal distribution with mean zero and variance σ^2 and independent from U_{it}; U_{it} s are non-negative random variables associated with the technical inefficiency of production.

Wage augmented translog stochastic frontier production model

We used a stochastic frontier production model for panel data proposed (Battese and Coelli, 1992), in which inefficiency effects are assumed to be distributed as truncated normal variables withtime varying inefficiency effects. In investigating the influence labor wage awareness efficiency a wage augmented standard Translog production function with composed errors can be defined as:

$$\ln y_i = \beta_0 + \sum_{i=1}^{7} \beta_i \ln x_{it} + \frac{1}{2}\sum_{i=1}^{7}\sum_{j=1}^{7} \beta_{ij} \ln x_{it} \ln x_{it} + \sum_{i=1}^{7}\sum_{i>j}^{7} \beta_{ij} \ln x_{it} \ln x_{it} + v_{it} - u_{it} \quad (2)$$

Given the specifications of the stochastic frontier production function, defined by equation (1) and (2), the technical efficiency of the i-th industry in the t-th year is defined by (Battese and Coelli, 1988; Taymaz and Saatci, 1997; Kumbhakar and Lovell, 2000).

$$TE_{it} = \exp(-U_{it}) \quad (3)$$

The technical efficiency can be predicted using the Computer program FRONTIER Version 4.1 (Coelli, 1996a) which calculates the maximum-likelihood estimators of the predictor for equation (5) that is based on its conditional expectation (Battese and Coelli, 1993).

In stochastic frontier production model defined by equation (1) and (2), using the composed error terms we utilize the parameterization of (Battese and Corra ,1977) who replace σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$. In the truncated and half-normal distribution, the ratio of firm specific variability to total variability γ is positive and significant, implying that industry specific technical efficiency is important in explaining the total variability of output produced.

Hypothesis test

In this study the hypothesis tests are conducted to determine the distribution of the random variables associated with the existence of technical inefficiency and the residual error term. Test of hypothesis for the parameters of the frontier model is conducted using the generalized likelihood-ratio statistics, λ defined by

$$\lambda = -2\ln\left[L(H_0)/L(H_1)\right], \quad (4)$$

Where $L(H_0)$ is the value of the likelihood function for the frontier model, in which parameter restrictions specified by the null hypothesis, H_0, is imposed; and $L(H_1)$ is the value of the likelihood function for the general frontier model. If the null

Table 2. OLS Estimates of Cobb-Douglas production function.

Variable	Parameters	Coefficients	S.E.	T-ratio
Constant	β_0	1.131*	0.288	3.916
X_1	β_1	0.257*	0.023	10.979
X_2	β_2	0.0891***	0.054	1.624
X_3	β_3	- 0.099**	0.055	-1.801
X_4	β_4	0.075@	0.074	1.021
X_5	β_5	-0.107***	0.075	-1.419
X_6	β_6	0.710*	0.021	33.732
X_7	β_7	0.014	0.012	1.159
Sigma Square	σ^2	0.200		
Ln-Likelihood		-167.457		

*, **, *** are significant at 1, 5 and 10% levels respectively. @ means insignificant, S.E. = Standard error.

hypothesis is true, then λ has approximately a chi-square (or mixed square) distribution with degrees of freedom equal to the difference between the parameters estimated under H_0 and H_1, respectively. If the null hypothesis involves $\gamma = 0$, expressing that the technical inefficiency effects are not present in the model. Setting the null hypothesis that $H_0 : \eta = 0$ provides the technical inefficiency is time-invariant. If parameter η is positive, the technical efficiency of the sample country increases over time and vice versa. However, if parameter η is zero, then the country effect will be constant over time. Again, a half-normal distribution as the most appropriate assumption for the inefficiency distribution is undertaken to the model. The half-normal distribution is a special case of the truncated normal distribution, and implicitly involves the restriction $H_0 : \mu = 0$. If parameter μ is zero, then country effect would have a half normal distribution instead of a truncated normal distribution.

RESULTS AND DISCUSSION

Ordinary least square estimation

At the first step we carried out the ordinary least square estimation to assess the significance of the seven input variables in Table 2. The parameter estimates of this OLS method showed the average performance of the industries or firms. The coefficient of the capital input was found to be highly significant. Manual labor and non-manual labor are also significant. The wage rate for non-manual labor was found to be significant. The cost of raw material used in this analysis was established highly significant effect on the production function. The wage rate for manual labor and year were found to be insignificant. It was apparently implied that all input variables used in this method except wage rate for manual labor were essential contributing factors for enhancing the productivity of the manufacturing industries.

Maximum-likelihood estimation from wage Augmented Cobb-Douglas production frontier

The maximum likelihood estimates of wage augmented Cobb-Douglas frontier production function were presented in Table 3. We Model (1) corresponding to wage augmented Cobb-Douglas frontier function presented the basic specifications. In model (1) the parameter estimate of capital was found positive, and highly significant at 1% level. Manual labor coefficient was observed significant at 10% level for the model (3) and model (4) while the parameter estimate for non-manual labor was not significant for each of the models. Therefore we concluded that capital was found to be more crucial than labor in determining output in Bangladeshi manufacturing industries.

The results also indicated that the technical inefficiency effects tended to upwards over time since the estimated value of η was negative and significant. However, the γ-estimate associated with the variance of the technical inefficiency effect was found large and significant. Furthermore, with regard to the specification of the error term, the estimation results it was shown that the traditional i.e. Cobb-Douglas production function was observed strongly rejected, implying that the technical inefficiency effects associated with this industry was significant.

Maximum-likelihood Estimation from Wage Augmented Translog Production Frontier

The functional specification of the stochastic production frontier was determined by testing the adequacy of the Translog specification to the data relative to the more restrictive Cobb-Douglas. Table 5 reports this test, where the null hypothesis was rejected showing that the Translog specification fitted the data better than the Cobb-Douglas. Table 4 presented the maximum likelihood estimates of conventional wage augmented Translog frontier production functions. Model (1) presented the basic specifications, that is, all the input variables were included in this model (1) and we did not use wage variable on the model (4).

In model (1) the augmented the production frontier was

Table 3. Maximum-likelihood Estimates of the Cobb-Douglas Stochastic Production Frontier

Variable	Parameter	Cobb-Douglas							
		Model (1)		Model (2)		Model (3)		Model (4)	
		Coe	t-ratio	Coe	t-ratio	Coe	t-ratio	Coe	t-ratio
constant	β_0	4.459*	10.384	4.396*	9.578	4.259*	10.149	4.434*	9.201
X_1	β_1	0.197*	6.798	0.210	0 .751	0.215*	7.721	0.212*	7.558
X_2	β_2	0.055	1.014	0.050	1.005	0.064***	1.332	0.076***	1.569
X_3	β_3	0.059	1.048	0.041	0.750	0.024	0.478	0.024	0.499
X_4	β_4	0.026	0.431			0.044	0.769		
X_5	β_5	0.075	1.171	0.076	1.290				
X_6	β_6	0.540*	20.112	0.544*	19.251	0.552*	20.595	0.551*	19.976
X_7	β_7	0.064*	4.684	0.069*	5.322	0.067*.	4.811	0.070*	5.249
Variance parameter									
Sigma	σ	0.729*	8.410	0.735*	8.601	0.706*	8.112	0.724*	7.107
Sigma-Squared (u)	σ_u^2	0.456		0.465		0.421		0.446	
Sigma-Squared (v)	σ_v^2	0.076		0.075		0.078		0.078	
Lamda (σ_u/σ_v)	λ	2.449		2.489		2.323		2.391	
ε		0.532		0.541		0.499		0.524	
$\mathrm{var}(u)/\mathrm{var}(\varepsilon)$		0.857		0.859		0.843		0.851	
Gamma	γ	0.858*	35.363	0.860*	34.406	0.843*	29.947	0.852*	26.002
Mu	μ	1.353*	6.276	1.364*	5.669	1.298*	5.956	1.337*	5.767
Eta	η	-0.022*	-2.252	-0.025*	2.730	-0.024**	-2.262	-0.022**	-2.114
Ln-likelihood		-98.221		-98.447		-98.997		-99.097	
Mean Efficiency		.309		.309		.326		.322	

*, **, *** are significant at 1, 5 and 10% respectively.
*Model (1) means with WRML and WRNML
*Model (2) means without WRML
*Model (3) means without WRNML
*Model (4) means without WRML and WRNML

Table 4. Maximum-likelihood estimates for parameters of the translog stochastic frontier production function.

Variable	Parameters	Translog production function							
		Model(1)		Model(2)		Model(3)		Model(4)	
		Coe	t-ratio	Coe	t-ratio	Coe	t-ratio	Coe	t-ratio
Constant	β_0	7.221*	7.461	6.533*	4.896	5.105*	5.203	4.817*	4.823
X_1	β_1	0.025	0.109	0.017	0.099	0.079	0.370	0.026	0 .162
X_2	β_2	-0.562	-1.077	-0.340	-0.782	-0.928*	-2.251	-0.909*	-2.507
X_3	β_3	-0.302	-0.553	-0.251	-0.484	0.391	0.998	0.459	1.311
X_4	β_4	-0.566	-.848			-0.381	-0.743		
X_5	β_5	-0.801	-1.193	-0.912	-1.660				
X_6	β_6	0.931*	4.886	0.869*	5.994	0.947*	5.370	0.888*	6.355
X_7	β_7	-0.025	-.196	-0.030	-0.248	-0.136	-0.111	-0.113	-1.087
X_1^2	β_{11}	0.034*	3.411	0.035*	3.546	0.043*	4.433	0.044*	4.915
X_2^2	β_{22}	-0.057	-.871	-0.024	-0.707	-0.026*	-4.722	-0.003	-0.118
X_3^2	β_{33}	-0.004	-.089	0.034	0.860	-0.019	-0.556	-0.011	-0.351

Table 4 contd.

X_4^2	β_{44}	-0.002	-.021			0.041	0.560		
X_5^2	β_{55}	0.044*	3.178	0.375*	3.815				
X_6^2	β_{66}	0.038*	4.701	0.036*	4.699	0.037*	4.853	0.035*	4.605
X_7^2	β_{77}	0.019*	5.023	0.019*	4.921	0.015*	3.891	0.016*	4.789
$X_1 * X_2$	β_{12}	0.096**	1.768	.089**	1.803	0.098**	2.042	0.117*	2.511
$X_1 * X_3$	β_{13}	-0.038	-.695	-0.048	-0.899	-0.061	-1.195	-0.067	-1.316
$X_1 * X_4$	β_{14}	-0.009	-.124			-0.014	-.286		
$X_1 * X_5$	β_{15}	0.006	.103	-0.0005	-.0136				
$X_1 * X_6$	β_{16}	-0.074*	-4.686	-0.071*	-4.401	-0.087*	-5.80	-0.092*	-6.120
$X_1 * X_7$	β_{17}	-0.006	-.810	-0.010	-1.571	-0.004	-0.644	-0.007	-1.064
$X_2 * X_3$	β_{23}	0.061	.783	0.008	0.195	0.041	0.661	0.016	0.379
$X_2 * X_4$	β_{24}	0.073	.889			0.109***	1.473		
$X_2 * X_5$	β_{25}	-0.192**	-1.784	-0.182**	-1.883				
$X_2 * X_6$	β_{26} 0	-0.003	-0.068	-0.002	-0.044	-0.053***	-1.328	-0.052***	-1.321
$X_2 * X_7$	β_{27}	-0.008	-0.268	0.005	0.239	0.005	0.197	0.008	0.385
$X_3 * X_4$	β_{34}	0.849	0.783			0.049	0.626		
$X_3 * X_5$	β_{35}	0.179***	1.388	0.211***	1.959				
$X_3 * X_6$	β_{36}	-0.023	-0.469	-0.005	-0.115	0.024	0.562	0.041	0.982
$X_3 * X_7$	β_{37}	-0.003	-0.125	-0.008	-0.337	-0.007	-0.304	-0.009	-0.420
$X_4 * X_5$	β_{45}	-0.048	-0.243						
$X_4 * X_6$	β_{46}	0.019	0.273			-0.028	-0.573		
$X_4 * X_7$	β_{47}	-0.022	-0.860			-0.003	-0.149		
$X_5 * X_6$	β_{56}	-0.121**	-2.002	-0.100**	-2.307				
$X_5 * X_7$	β_{57}	-0.042***	-1.452	-0.046***	-1.923				
$X_6 * X_7$	β_{67}	0.017**	2.257	0.016**	2.107	0.010***	1.407	0.008***	1.334
Variance parameter									
Sigma	σ	0.557*	5.371	0.852***	1.513	0.658*	7.317	0.630*	6.560
Sigma-Squared (u)	σ_u^2	0.261		0.677		0.383		0.343	
Sigma-Squared (v)	σ_v^2	0.050		0.049		0.051		0.054	

Table 4 contd.

Lamda (σ_u/σ_v)	λ	2.284	3.489	2.740	2.520
ε		0.311	0.726	0.434	0.397
$\mathrm{var}(u/\varepsilon)$		0.839	0.932	0.882	0.864
Gamma	γ	0.839* 19.523	0.932* 19.615	0.882* 36.912	0.864* 29.456
Mu	μ	1.022* 5.373	1.134* 3.138	1.238* 6.099	1.173* 5.556
Eta	η	-0.025** -2.058	-0.326*** -1.715	-0.021*** -1.910	0.023*** -1.818
Ln-Likelihood		-39.726	-39.256	-36.266	-37.325
Mean Efficiency		0.398	0.3882	0.3226	0.3585

*, **, *** are significant at 1, 5 and 10% respectively.

formulated by the wage rate relative to the industry average *WRML* and *WRNML*; its coefficient signs were negative and insignificant. The parameter estimate of capital was positive, but insignificant. Square term of the capital was found highly significant at 1% level in each of the models. Manual labors were significant at 1% level for both the model (3) and model (4) and were insignificant for the remaining models. The parameter estimates for non-manual labor was found not significant for each of the models. The similar results were observed once again that capital was more crucial than labor in determining output in Bangladesh manufacturing industries. Wage rate for manual labor and wage rate for non-manual labor were found to be negative and statistically insignificant. From the findings of "Sollow codition" (Sollow, 1979) implied that the estimated coefficients of the wage level and physical labor input in the production function should be same. The estimated results indicated that the Sollow condition does not hold since the coefficient of the relative wage level were significantly varied than the coefficients of the labor variable. Based on the asymptotic t-values, the cost of raw materials coefficient came out to be statistically significant at 1% level in each of the models. All other coefficients except square term of capital and cost of raw materials turned out to be statistically insignificant. This is rather a surprising result. This altogether indicated that the square term of capital and cost of raw materials variable are extraordinarily important for the manufacturing industries of BangladeshThe new variable time trend included in this model was found totally insignificant. But the square product of year was significant at 1% level and the sign of this square of time trend is positively indicated that the technical efficiency turned down over time. The second order parameters β_{11} *and* β_{66} were expected to show negative signs but they appeared positive and statistically significant. So the wrong signs did not considerably distort the results.

The coefficient of the interaction variables between capital, manual labor and cost of raw materials driven out to be statistically significant at 1% level of significance based on the asymptotic t-values whereas the interaction between capital and non-manual labor, and interaction between capital and wage rate for manual labor were found to be negative and insignificant. The interaction between capital and wage rate for non-manual labor was found positive but insignificant for the model (1) and it was found to be negative for the model (2). The parameter estimates of the interaction between manual labor and non-manual labor with the time trend turned out to be insignificant. The interaction between manual labor and wage rate for manual labor was found significant only for the model (3).

The interaction between manual labor and wage rate for non-manual labor came out to be significant at 5% level of significance for both the model (1) and model (2). The interaction between non-manual labor and wage rate for non-manual labor was identified significant at 10% level for both the model (1) and model (2). The second order coefficient of wage rate for non-manual labor and cost of raw materials was negative and significant. And also interaction between these two variables (wage rate of non-manual labor and cost of raw materials) with the time trend found to be significant.

As the variance parameter, γ which lies between 0 and 1, indicated that technical inefficiency was stochastic and it was relevant to obtain an adequate representation to the data. The values of the variance parameter are observed 0.84, 0.93, 0.88 and 0.86 for the respective models. These interpreted that the variance of the inefficiency effects was a significant component of the total error term variance and then, firms deviations from

Table 5. Generalized Likelihood-Ratio Tests of Hypothesis for Parameters of the Stochastic Frontier Production Function for Manufacturing Industries in Bangladesh.

Null hypothesis	Log likelihood	Test statistics λ	Critical value	Decision
Wage Augmented Translog Model (1)	-39.726			
$H_0 : \beta_{ij} = 0, i \leq j = 1,2.3,4,5,6,7$	-98.221	116.99	18.3	Reject H_0
$H_0 : \beta_7 = \beta_{i7} = 0, i = 1,2,3,4,5,6,7$	-45.821	12.19	11.07	Reject H_0
$H_0 : \gamma = 0$	-109.22	138.997	7.05	Reject H_0
$H_0 : \mu = 0$	-39.805	0.158	3.84	Reject H_0
$H_0 : \eta = 0$	-42.568	5.684	3.84	Reject H_0

All critical values are at 5% level of significance.

*The critical values are obtained from table of Kodde and Palm (1986). The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution, because the restriction defines a point on the boundary of parameter space.

the optimal behavior were not only due to random factors. Since the estimated σ^2 and γ were statistically significant at 1% level so these indicated the justification of using a stochastic frontier production model in this case because of the presence of technical inefficiencies in manufacturing industries in question.

Mean technical efficiencies were observed 39.8, 38.82, 32.26 and 35.85 respectively for each of the models. These were interpreted as follows: In the short run, there was a scope for increasing manufacturing production by 40, 39, 32 and 36% by adopting technologies and techniques used by the best practice manufacturing firms. These also suggested that, on the average; about 60, 61, 68 and 64% of production yield are lost due to inefficiency.

Tests of hypothesis

To test the hypothesis, a nested hypothesis was performed to determine whether the Cobb-Douglas specification was an adequate representation of the frontier production function or not. This test used the log likelihood ratio test. Table 5 outlined the results of the null hypothesis. The null hypothesis, $H_0 : \beta_{ij} = 0$ was rejected in favor of the Translog production function.

The second null hypothesis $(H_0 : \beta_7 = \beta_{i7} = 0,\ i=1,2,3,4,5,6,7)$ explored the test that there was no technical progress for the frontier as it was rejected the hypothesis, implying the production frontier shifted over time. The null hypothesis $H_0 : \gamma = 0$, that specified no technical inefficiency effects which was strongly rejected for all industries. This showed that Translog production function was not equivalent to the traditional average response function. Then, the frontier model could not be reduced to a mean response production function (OLS estimation) to represent the data precisely.

Given the specification of the stochastic frontier with time varying inefficiency effects, the null hypothesis $H_0 : \eta = 0$ and $H_0 : \mu = 0$, which also explored that the technical inefficiency effects are time invariant and half normal distribution, were rejected indicated that technical inefficiency effect varied significantly over time and that truncated normal distribution was preferable to the half normal distribution for inefficiency effect.

CONCLUSION

In this study we experienced the implication of wage efficiency hypothesis for the manufacturing industry of Bangladesh. We anticipated both Cobb-Douglas production function and Translog production function. Translog Production function was found better characterized data than Cobb-Douglas production function. Wage rate for manual labor and wage rate for non-manual labor were found to be negative and statistically insignificant. The interaction between manual labor and wage rate for manual labor was found significant only for the model (3). In those analyses we can say that in developing country like Bangladesh administrator body is not showing much interest about giving much wage to labor and also labor are not much conscious about what they are receiving. Usually we can see that higher wage enhances workers effort and as well as production output. But in this study we see that the wage level is not in a satisfactory position which can produce increase production and we get low production output. On the basis of region wage level differs significantly so further research can be done by researchers in the context of wage augmented model with regional wage level data.

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PROGRAMME

17th December, 2009

Time: 10:30 – 11:30 Session: Opening Ceremony

Venue: Council Building, BUET

Time: 11:30 – 13:00 Session: Keynote 01

Venue: Council Building, BUET

Session Chair: Prof. M. Anwar Hossain

Keynote Talk : Prof. Saleh Tanveer

16MC09-K01: Saleh Tanveer

Professor of Mathematics, The Ohio State University, 231 West 18th Avenue Columbus, OH 43210-1174, U.S.A.

Regularity, singularity and well-posedness of some mathematical models and their physical implications

Time: 13:00 – 14:30, Lunch and Prayer Break

Time: 14:30 – 16:00 Session: 1A

Venue: Post Graduate lecture room (Math)

Session Chair: Prof. Khodadad Khan (DU)

Invited talk: Prof. Anjan Mukherjee

16MC09-032: Anjan Mukherjee

Professor and Head, Department of Mathematics, Tripura University, Surjyamaninagar, Agartala-799130, Tripura, India.
E-mail: anjan2002_m@yahoo.co.in

Lower and Upper Minimal Weakly Δ-Semi Continuous Fuzzy Multifunctions

Contributory talks

16MC09-012: Mostak Ahmed [a], M. Alamgir Hossain[b]

[a]Institute of Natural Sciences, United International University, Dhaka-1209
[b]Department of Mathematics, Jagannath University, Dhaka-1100

Solution of Transcendental Equations Using Quadratic False-Position Method

17th December 2009 (Thursday)

Time: 16:00 – 16:15 Tea Break

Time: 16:15 – 18:00 **Session: 2A**

Venue: Post Graduate Lecture room (Math)

Session Chair: Prof. Md. Fazle Hossain (CU)

Invited talk: Prof. Md. Azhar Hussain

16MC09-054: **Md. Azhar Hussain**
Department of Mathematics, Veer Kunwar University, Ara - 802301, Bihar, India. email: azharhu@gmail.com
Fractional Integeration of H-Functions of Multivariable and Applications

Contributory talks

16MC09-005: **Kumar Sanjeev[1], Pathak Pooja[2]**
[1]Dept. of Mathematics, Dr. B. R. Ambedkar University,IBS, Khandhari, Agra, India [2]Dept. of Applied Sciences, GLA Institute of Technology and Management, Mathura, India sanjeevibs@yahoo.co.in
Fuzzy Based Pricing Model for Old Age Insurance

16MC09-056: **Md. Shafiqul Islam**
Department of Mathematics, University of Dhaka, Dhaka-1000, Bangladesh Email: mdshafiqul@yahoo.com
Numerical Solutions of fourth order linear BVP using Bernstein polynomials

16MC09-068: **Ramit Azad[1] and Ermolaev Yu. G.[2]**
[1]Department of Electronics and Communication Engineering East West University, Dhaka, Bangladesh rmt_azad@yahoo.com
[2]Department of Theoretical Physics, Peoples Friendship University of Russia, Moscow.
Evaluation of integrals using the error function and error function of imaginary argument

16MC09-003: **Md. Azizul Baten and Anton Abdulbasah Kamil**
School of Distance Education, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia. Email: baten_math@yahoo.com; anton@usm.my
An Optimal Control Approach to Inventory-Production Systems with Weibull Distributed Deterioration

16MC09-020: **Muhibul Haque Bhuyan**
Department of Electronics and Telecommunication Engineering,
Daffodil International University, 102 Shukrabad, Dhanmondi, Dhaka 1207
E-mail: muhibulhb@daffodilvarsity.edu.bd
Comparative Study of Different Root Location Methods Using MATLAB Programs

16MC09-092: **Payer Ahmed**
Department of Mathematics, Jagannath University, Dhaka -1100

Date: December 22-23, 2009

Venue: Senate Bhaban, University of Dhaka, Bangladesh

The second International Conference of Global Business and Management Forum 2009 (GBMF), USA was held at Senate Bhaban, University of Dhaka, Bangladesh on December 22nd and 23rd, 2009. The conference was jointly organized by the Department of Finance, University of Dhaka, Bangladesh and the GBMF-USA.

LIST OF PAPERS

Category	Session	Code No.	Tile	Author
F	1-A	12	Strategy & Structure in a Virtual Organization	Nazim U Ahmed & Shushil S. Sharma
F	1-A	23	Searching for shoes that feet the aching feet	Parvez Mahmud
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D	1-B	8	Missing link between the Draft CC for TCs and CSR paradigms	Mia Mahmudur Rahim
C	2-A	5	Global Financial Crisis & Recession: Experiences From The Past and Lesson for Bangladesh	Taneem Muzaffar, Parvez Karim Abbasi & M.A. Hossain Khan
C	2-A	32	Implications of Global Financial Crisis for International Negotiations on Climate Change Challenges & Responses	Mostafa M. Naser
C	2-A	21	The Global Financial Crisis: Challenges and Opportunities for the Bangladesh Economy	Muhammad Mahboob Ali, Anisul M. Islam
C	2-A	25	The US Financial Crisis, Global Recession and Monetary Policy: An Assessment from the East Asian Perspective	A.M. Akhtar Hossain
C	2-A	6	Impact of Global Recession & Possible Remedies for Bangladesh	Syed Kamrul Islam & Amitabh Bose Bapi
H	2-B	9	Male Wage Advantage in Pakistan	Javed Ashraf
H	2-B	17	Counter-Cyclical Advertising-Selling-Efforts (Ase) To Reduce Commodity Price Luctuations	Gerrit Th.B. de Vos Ph.D
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A	3-A	2	Microfinance in India	Kamir Kothari
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B	3-B	30	Inventory Mangement System with Hazardous Items of Two Parameter Exponential Distribution	Mr. Azizul Baten, Anton Abdulbasah Kamil
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G	4-A	36	Financial Performance Measures and Relationship Development Within a Bilateral Governance Stucture	Quamrul Islam
G	4-A	15	Bank Governance Effectiveness Towards Regulatory Compliance	Javed Anwar and Sheikh Tanzila Deepty
G	4-A	34	The Evolution of Corporate Governance Practices in Bangladeshi Banks with the Implementation of the Code of Corporate Governance	Dr. Jesmin Islam
G	4-A	22	Global Financial Crisis: A Comparative study of three representatives (US, India and Bangladesh) of three different worlds - developed, developing and least –developed	Nalin Bharti (Ph.D. JNU)
E	4-B	33	Impact of Company Learning and Growth	Majidul Islam, Dr. Yi-

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J	5-A	1	Analysis of Management Tools	M. Bilal Quereshi & M. Shuaib Quereshi
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I	5-B	18	Psychological Disorder In The Indian Economy During Recession	Dr. Manasranjan Dashmishra, Reader, Dr. Hitendra Bargal, Professor, Mrs. Pooja Pateria, Doctoral Fellow
I	5-B	13	Investors Preference on IPOs in India	Sasi Kumar & P. Vikkraman
I	5-B	31	Value Investing Strategy: Investment Strategy for all Market Conditions	Dr. Tejinder Singh Rawal

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Saturday January 16, 2010

- **Saturday January 16, 2010, 7:00 a.m.-8:45 a.m.**
  MAA Minority Chairs Breakfast Meeting
  Foothills D, Marriott San Francisco

- **Saturday January 16, 2010, 7:30 a.m.-2:00 p.m.**
  Joint Meetings Registration
  First Floor Lobby, Moscone

- **Saturday January 16, 2010, 7:30 a.m.-10:50 a.m.**
  AMS Special Session on Biomathematics: Modeling in Biology, Ecology, and Epidemiology, II
  Room 3003, 3rd Floor, Moscone
  Organizers:
  Olcay Akman, Ilinois State University oakman@ilstu.edu
  Linda Allen, Texas Tech University
  Timothy D. Comar, Benedictine University
  Sophia Jang, Texas Tech University
  Lih-Ing Roeger, Texas Tech University lih-ing.roeger@ttu.edu

  - 7:30 a.m.
    Integrin Dynamics in Motile Cells: A Stochastic Approach.
    Hannah L Callender*, University of Portland
    Hans G Othmer, University of Minnesota
    (1056-92-614)
  - 8:00 a.m.
    Organism-Associated and Mat-Forming Metagenome Statistical Analysis using Random Forests Algorithms.

- **Saturday January 16, 2010, 1:00 p.m.-5:25 p.m.**

AMS Session on Optimization and Control
Room 3022, 3rd Floor, Moscone

- 1:00 p.m.
  Generalized Steiner and Schwarz Symmetrization.
  Frank Morgan*, Williams College
  Alexander Diaz, University of Puerto Rico
  Nate Harman, University of Massachusetts, Amherst
  Sean Howe, University of Arizona
  David Thompson, Williams College
  (1056-49-401)
- 1:15 p.m.
  Higher Order Sufficient Conditions for Strict Minimality in Smooth Scalar Optimization.
  Elena Constantin*, University of Pittsburgh at Johnstown
  (1056-49-1049)
- 1:30 p.m.
  The asymptotic behavior of power-law functionals and applications.
  Cristina Popovici*, NDSU
  (1056-49-1104)
- 1:45 p.m.
  On the Principle of Smooth Fit for Some Convex Optimal Control Problems.
  Jesus A. Pascal*, American University of Nigeria
  (1056-49-1194)
- 2:00 p.m.
  Optimal Control and its Application to Hepatitis C Treatment.
  Siddartha P. Chakrabarty, Indian Institute of Technology Guwahati, India
  Hem R Joshi*, Xavier University, Cincinnati OH
  (1056-49-1645)
- 2:15 p.m.
  Break
- 2:30 p.m.
  Application of Nonlinear Optimization in the Design of a Doubly Convergent Multiple-Beam Electron Gun.
  Adam Attarian*, North Carolina State University
  Tallis J William, North Carolina State University
  Hien T Tran, North Carolina State University
  Lawrence Ives, Calabazas Creek Research, Inc.
  (1056-49-1654)
- 2:45 p.m.
  The Minimal Time Problem On Stratified Domains.
  Richard C Barnard*, Louisiana State University
  Peter R Wolenski, Louisiana State University
  (1056-49-1675)
- 3:00 p.m.
  Analysis of Tendon-Reinforced Piecewise-Isotropic Pressurized Membranes.

Michael C. Barg*, Niagara University
Jieun Lee, The George Washington University
Frank Baginski, The George Washington University
(1056-49-1690)

- 3:15 p.m.
  Sensitivity-Based Optimization Applied to Equations Modeling Film Casting.
  David C Szurley*, Francis Marion University
  (1056-49-1702)
- 3:30 p.m.
  Morrey Regularity for Asymptotically Convex Variational Problems with (p,q) Growth.
  Kyle Fey*, University of Nebraska - Lincoln
  Mikil Foss, University of Nebraska - Lincoln
  (1056-49-1850)
- 3:45 p.m.
  A Modified Piecewise Constant Mumford-Shah Model Based Simultaneous Image Segmentation and Registration.
  Jung-Ha An*, California State University Stanislaus
  Yunmei Chen, University of Florida
  (1056-49-1967)
- 4:00 p.m.
  Break
- 4:15 p.m.
  Generalized shearlets and the extended metaplectic group.
  Emily J King*, National Institutes of Health / Norbert Wiener Center UMD
  Wojciech Czaja, University of Maryland
  (1056-43-1718)
- 4:30 p.m.
  Remarks on the Apportionment of the U. S. House of Representatives.
  Daniel D Sheng*, Westwood High School
  Edwin Oxford, Baylor University
  (1056-00-511)
- 4:45 p.m.
  An Estimate of The Radius of an Attraction Ball for TV-Minimization Problems in Image Denoising.
  L. A. Melara*, Shippensburg University
  A. J. Kearsley, NIST
  (1056-90-1776)
- 5:00 p.m.
  Production Inventory Planning in a Stochastic Manufacturing System with Discounted Cost.
  Anton Abdulbasah Kamil*, Universiti Sains Malaysia
  Md Azizul Baten, Universiti Sains Malaysia
  (1056-90-176)
- 5:15 p.m.
  Relaxed Matching for the Method of Controlled Lagrangians.

David A Long*, North Carolina State University
Anthony M Bloch, University of Michigan
Jerrold E Marsden, California Institute of Technology
Dmitry V Zenkov, North Carolina State University
(1056-70-1372)

1056-90-176 **Anton Abdulbasah Kamil*** (anton@usm.my), School of Distance Education, Universiti Sains Malaysia, 11800 Penang, Penang, Malaysia, and **Md Azizul Baten**, School of Distance Education, Universiti Sains Malaysia, 11800 Penang, Penang, Malaysia. *Production Inventory Planning in a Stochastic Manufacturing System with Discounted Cost.*

The paper is concerned with the production inventory planning in a stochastic manufacturing system with minimizing the expected discounted production cost control problem. We develop the optimal production inventory control problem associated with the reduced (one-dimensional) Hamilton-Jacobi Bellman equation. The analysis proceeds with a study of the developed production inventory control problem with a discounted cost. We establish the uniqueness solution of this Hamilton-Jacobi-Bellman equation associated with this problem. (Received August 11, 2009)

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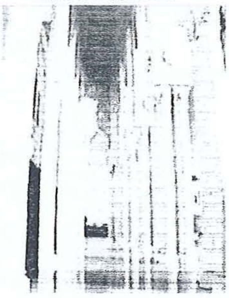
Home Site Map

ICMS 10

- Home
- Committees & Sponsors
- Participants
- Registration
- Abstract Submission
- Keynote Lectures
- Speakers & Abstract
- Program
- Conference Journals
- Conference proceedings
- Special Sessions
- Visa Information
- Accommodations & Travel
- Social Events
- Contacts & Useful Links
- Mathematics & Statistics Department
- Back to AUS Home



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Deadline to submit full paper for the conference proceedings: February 15, 2010

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Paper Reference	Paper Title	Corresponding Author
1001	On the Homotopy perturbation method for Fuzzy system of linear equations	M. Matinfar
1005	Kernel-Wavelet estimation and empirical distribution of wavelet coefficients for regularity regression function	Mahmoud Afshari
1009	On μ-singular and μ-extending modules	Yahya Talebi
10022-I	Non-commutative harmonic analysis on the Heisenberg group	Kahar El-Hussein
10022-II	Fourier transform and invariant differential operators on nipotent Lie group HxR*+	Kahar El-Hussein
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10029-I	Sum of eigenvectors and conjugate vectors in the dual space D^n	Abolfazl Talesshian
10029-II	Investigate the gauss equation and curvature tensor in dual space D^n	Abolfazl Talesshian
10037	Almost periodic solutions for an impulsive delay population model	Jehad O. Alzabut
10040	Inference in Bayesian networks using D-Separation	Linda Smail
10041-I	On the M-fuzzy metric spaces with using weak** commuting maps	Faryaneh Fadaei
10041-II	On the D*- metric spaces with property (E.A)	Faryaneh Fadaei
10044	Common fixed point theorems in fuzzy metric spaces through conditions of integral type	Shaban Sedghi
10052	τ-Noncosingular Modules and Dual Baer Modules	D. Keskin
10053	Two decades of static modules (1990-2010)	S. Naumann
10061	Extension of stable functions and Vietoris' theorem	A. Swaminathan
10066	Some Generalizations of Quasi-Projective Modules	B. Kuru
10073	Universality of transition to chaos in all kinds of nonlinear differential equations	Nikolai A. Magnitskii
10082	Application of restricted adaptive cluster sampling design for the production of cotton in Iran	Reza Shahi
10084	Effect of measurement error on multivariate process capability indices	Bahram Sadeghpour Gildeh
10090	Szeged index of some graphs	A. Seyed Mirzaei
10091-I	Odd graceful labeling of cyclic snakes	El- Said Badr
10091-II	On the derived subgraphs conjecture	El- Said Badr

100310	Homotopy analysis method for solving heat transfer and axisymmetric stagnation flow on a moving plate	Ahmad Doosthoseini1
100312	One-sided vector fields as a one-parametric semigroups of diffeomorphisms	P. Miskinis
100316	A two-stage shrinkage testimator of the mean of exponential distribution	Z. A. Al-Hemyari
100317	Global existence of solution a system of reaction-diffusion	Dehimi Melouka
100318	Proof of Euler's Theorem from the 18th century and Geogebra's proof from the 21st century	Anton Vrdoljak
100323-I	Mathematical modeling of gas turbine engine start mode	M. .Montazeri-Gh
100323-II	Investigation of superior driving features using Statistical Analyses	Morteza Montazeri-Gh
100328	Using the relationship between periodic continued fraction and quadratic irrationals: ASAB - III Cipher	Ahmet Şükrü Özdemir
100330	The stability analysis depending number of predation in discrete-time population model and alee effect	H. Kose
100332	Exponentially convex functions on hypercomplex systems	Buthinah Bin Dehaish
100334	The comparison of the education of operations and fractions supported by mental calculation in “nihayatu'l albab” with recent education	Satı Ceylan
100336	Locally finite lie algebras and Serre's theorem	Malihe Yousofzadeh
100341	On fibo-Pascal matrix via k-Fibonacci and k-Pell matrices	Mustafa Asci
100345	New algorithms for some triad designs	Tareq M. Abu Saa
100357	Exact travelling wave solutions of nonlinear (2+1)-dimensional dispersive long wave equation	Ahmad Neirameh
100359	On Pascal matrix involving k-Fibonacci like matrices.	Dursun Tasci
100365	Exponentiated Gamma distribution: Different methods of estimations	R. A. Bakoban
100369	Numerical solution of a model describing biological species living together by using legendre multiwavelet method	S. A. Youse
100371	On fuzzy θ-ω-continuity	Seema Mishra
100374	Inertial manifolds for singularly perturbed damped wave equations	Ahmed Bonfoh
100377	Embedding new class of graphs in hypercube	Habib Kobeissi
100378	Complex factorization formulas for Fibonacci and Pell numbers.	Meral Yasar
100379	Improving the localization of eigenvalues for complex matrices	Parviz Sargolzaei
100383	A method for regularization of ill-posed systems	Ali S. Hadi
100387	Ricatti solutions of production control in a stochastic manufacturing system with degenerate demand	Md. Azizul Baten
100392	From commutative algebra to algebraic geometry	Fouad El Zein
100401	Application of the Log-normal Distribution to the adsorption of Alkanes on 5a Zeolite	Dana Abouelnasr
100404	Direct sums of cyclically presented modules over rings of finite type	Babak Amini,
100408	Existence of solutions for quasilinear elliptic systems with Holder continuous nonlinearities and nonlocal boundary conditions	Mohammed Derhab

Optimal Fuzzy Control with Application to Discounted Cost Production Inventory Planning Problem

Md. Azizul Baten and Anton Abdulbasah Kamil,

Abstract— **A fuzzy optimal control model was formulated minimizing the objective function with discounted cost for the length of infinite horizon. We developed an equation of optimality in case of fuzzy optimal control problem. We revisited a special fuzzy control model with quadratic objective functional form for linear Liu's fuzzy control system. As an application, we investigated the infinite horizon production inventory planning problem with nonzero discount rate. We employed fuzzy optimal control to model inventory production planning problem with fuzzy variables and solved.**

Index Terms—Fuzzy optimal control, Linear quadratic problem, Production planning, Fuzzy control system.

I. INTRODUCTION

Applications of optimal control problems involve the control of dynamic systems that evolve over time either continuous-time systems or discrete-time systems. In order to deal with such systems, stochastic optimal control theory has been investigated and widely applied to physical, biological, finance, economics, production and inventory, marketing, maintenance and replacement, and the consumption of natural resources. Whenever the system is characterized with white noise and is represented by a controlled stochastic process then it is called stochastic control system which are described by Ito's stochastic differential equations. A traditional approach to solving optimal control problems consists of formulation of optimality conditions directly, use of the calculus of variations and Pontryagin's maximum principle (Bellman [2]), and then solving the resulting equations to obtain the solution to the problems.

Uncertainty is an important commodity in the modeling business and it is inherit in most dynamic systems. It is generally agreed that an important point in the evolution of the modern concept of uncertainty was introduced by Zadeh [13] via membership function. The use of fuzzy sets and fuzzy logic, in the social sciences appears to have been limited to mainly to psychology, with very little application to the analysis of economic problems and economic data. In the area of econometrics, however, there have been surprisingly few applications of fuzzy set/logic techniques. The way fuzziness has been applied widely in the modeling of control systems in different ways since the seminal contributions of Zadeh [13, 14] and his colleagues. The Mamdani [8] introduced fuzzy control system to control a steam engine and boiler combination by a set of control rules. The Takagi and Sugeno [10] and Sugeno and Kang [11] approach to dealing with fuzzy control system which were introduced for generation of fuzzy rules from a given input-output data set.

The most successful application area of fuzzy systems has undoubtedly been the area of fuzzy control. Fuzzy control theory has been applied to industrial production. Our presentation of fuzzy control includes the connection between fuzzy controllers and production planning problem, the importance of which has increasingly been recognized. The idea of applying fuzzy sets to control problems was presented for the first time more explicitly in Chang and Zadeh [4]. The actual research on fuzzy controllers was initiated by Mamdani and Assilian [7]; Mamdani [9]. Mamdani's work influenced other researchers to explore the applicability of fuzzy controllers to various control problems. Recently, fuzzy process and fuzzy calculus are introduced by Liu [6] as fuzzy counterpart of stochastic process and Brownian Motion who expressed fuzzy di□erential equation with Liu process in order to deal with the evolution of fuzziness with time. The control problem of production planning with discount rate has been studied by many authors like Fleming, Sethi and Soner [5], Sethi et. al. [12], and Baten and Kamil [1] in a stochastic manufacturing systems. Bensoussan et. al. [3] employed stochastic optimal control theory to model production planning problem for the continuous-time case and Zhu [15] for fuzzy optimal control with a finite horizon. But this paper seems to be a new literature establishing an alternative fuzzy optimal control with an application to fuzzy discounted cost production inventory planning problem for an infinite horizon.

The objective of this paper is to give an application to fuzzy production planning problem by using the developed equation of optimality. In order to this in section 2, we formulated the fuzzy optimal control problem with fuzzy process and we developed an equation of optimality in the context of fuzzy optimal control problem for an infinite horizon. In section 3, we proved that the value function of fuzzy linear quadratic control problem satisfied associated

Manuscript received December 17, 2009. This work was supported by Ministry of Higher Education of Malaysia under Fundamental Research Grant Scheme, No. 203/PJJAUH/671128, Universiti Sains Malaysia, Pinang, Malaysia.

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partial differential equation applying the equation of optimality. We also obtained the optimal feedback control in terms of state variable for linear fuzzy quadratic problem with discounted rate for an infinite horizon. The section 4 devoted with the result of an application to fuzzy production inventory planning problem.

II. FUZZY OPTIMAL CONTROL PROBLEM

We employed fuzzy optimal control to model inventory production planning problem with fuzzy variables and solved.

An optimization model is formulated on fuzzy optimal control problem to minimize the expected discounted cost control for Liu's fuzzy control system.

We assume that the dynamics of the state equation is governed by a special fuzzy differential equation based on Liu's fuzzy control system according to

$$dx_t = g(t,x_t,y_t)d_t + h(t,x_t,y_t)dL_t \tag{2.1}$$

where L_t is a standard Liu process at time t, x_t is the state variable at time t, y_t is a control at time t and $t \geq 0$.

The purpose of a fuzzy optimal control model is to choose the best cost control y_t such that x_t is optimized, that is,

$$J(y) = E\left[\int_0^\infty e^{-\rho t} F(t,x_t,y_t)dt\right] \tag{2.2}$$

over $y \in \mathrm{A}$ where A is denoted as the class of all admissible controls of fuzzy Liu processes, E represents the expected value operator of fuzzy variable and $\rho > 0$ constant non-negative discount rate.

We define the value function whose value is the minimum value of the objective function of the fuzzy optimal control problem (2.2) for the fuzzy control system, that is,

$$V(x) = \inf_{y_t} E\left[\int_0^\infty e^{-\rho t} F(t,x_t,y_t)dt\right] = \inf_{y_t} J(y) \tag{2.3}$$

Theorem 2.1 *We assume that the value function V (t, x) is a twice differentiable function on* $[0,\infty)\times\mathbb{R}$. *If* y_t^* *is an optimal control, then* y_t^* solves

$$\inf_y \left\{ F(t,x,y) - \rho V(t,x) + \frac{\partial V(t,x)}{\partial t} + g(t,x,y)\frac{\partial V(t,x)}{\partial x} \right\} = 0 \tag{2.4}$$

which is called equation of optimality.

Proof: At time 0, the present value of the objective function is given by $J = \exp(-\rho t)V(t,x)$. Then we observed that

$\frac{\partial J}{\partial t} = -\rho\exp(-\rho t)V(t,x) + \exp(-\rho t)\frac{\partial V(t,x)}{\partial t}$ and

$$\frac{\partial J}{\partial x} = \exp(-\rho t)\frac{\partial V(t,x)}{\partial x}$$

Using these relations in Bellman's (1957) equation of optimality, we obtain

$$\inf_y \{\exp(-\rho t)F(t,x,y) - \rho\exp(-\rho t)V(t,x) + \exp(-\rho t)\frac{\partial V(t,x)}{\partial t} + \exp(-\rho t)g(t,x,y)\frac{\partial V(t,x)}{\partial t}\} = 0$$

Dividing both sides by $\exp(-\rho t)$, then we obtain the equation of optimality (2.4). The proof is completed.

III. FUZZY LINEAR QUADRATIC CONTROL PROBLEM

In this section we propose a special fuzzy control model with quadratic objective functional form for linear Liu's fuzzy control system. The objective of this linear quadratic control model is to find an optimal control y_t^* which is a function of t. In order to solve this problem for the explicit feedback controller, we follow equation of optimality (2.4).

In general, we state the following fuzzy linear quadratic control problem for an infinite horizon:

$$J(t,x;y) = E\left[\int_0^\infty e^{-\rho t}\left(Fx_t^2 + Gy_t^2 + Hx_ty_t + Lx_t + My_t + N\right)dt\right]$$

where *F, G, H, L, M* and *N* are all real numbers.

The value function of this linear quadratic control problem is formulated as follows

$$V(t,x) = \inf_{y_t} J(t,x;y) \tag{3.1}$$

Subject to

$$dx_t = y_t dt + \sigma x_t dL_t, \tag{3.2}$$

where x is the initial state and V (0,x) = 0.

Theorem 3.1 *We assume that* $G \neq 0$. *Let V (t, x) be the value function of linear quadratic control model (3.1) and (3.2). Then the value function V (t, x) satisfies the following partial differential equation*

$$-\frac{1}{4G}\left(\frac{\partial V(t,x)}{\partial x}\right)^2 + \left(F - \frac{H^2}{4G}\right)x^2 - \left(\frac{HM}{2G} + L + \frac{H}{2G}\frac{\partial V(t,x)}{\partial x}\right)x - \frac{M}{2G}\left(\frac{M}{2} + \frac{\partial V(t,x)}{\partial x}\right) + N - \rho V(t,x) + \frac{\partial V(t,x)}{\partial t} = 0 \tag{3.3}$$

and the optimal control satisfies

$$y_t^* = -\frac{1}{2G}\left(\frac{\partial V(t,x)}{\partial x} + Hx + M\right).$$

Proof: It follows from the equation of optimality (2.4) that

$$\min_y U(y) = \min_y\Big\{\left(Fx_t^2 + Gy_t^2 + Hx_t y_t + Lx_t + My_t + N\right) - \rho V(t,x) + \frac{\partial V(t,x)}{\partial t} + y_t \frac{\partial V(t,x)}{\partial t}\Big\} = 0 \quad (3.4)$$

where $U(y)$ denotes the term in the braces. Setting $\frac{\partial U(y)}{\partial y} = 0$ yields

$$2Gy + Hx + M + \frac{\partial V(t,x)}{\partial x} = 0 \ or$$

$$y_t^* = y = -\frac{1}{2G}\left(\frac{\partial V(t,x)}{\partial x} + Hx + M\right).$$

Substituting the last equality into the equation (3.4), we obtain

$$Fx^2 + \frac{1}{4G}\left(\frac{\partial V(t,x)}{\partial x} + Hx + M\right)^2 - \frac{Hx+M}{2G}\left(\frac{\partial V(t,x)}{\partial x} + Hx + M\right) + Lx + N - \rho V(t,x) + \frac{\partial V(t,x)}{\partial t} - \frac{1}{2G}\left(\frac{\partial V(t,x)}{\partial x} + Hx + M\right)\frac{\partial V(t,x)}{\partial x} = 0$$

which is just equation (3.6). The proof is complete.

Example 3.2 *We* assume that $G \neq 0$. Let V (t, x) be the value function of linear quadratic control model (3.1) and (3.2). We conjecture the value function $V(t,x) = Kx + \eta$, where $k > 0$, and $\eta > 0$. Then it follows from the equation of optimality (2.4) that

$$\min_y U(y) = \min_y\left\{Fx_t^2 + Gy_t^2 + Hx_t y_t + Lx_t + My_t + N - \rho Kx - \rho\eta + Ky_t\right\} = 0 \quad (3.5)$$

where $U(y)$ denotes the term in the braces. Setting $\frac{\partial U(y)}{\partial y} = 0$ yields

$2Gy + Hx + M + K = 0$,

from which we obtain the optimal control

$$y_t^* = y = -\frac{1}{2G}(K + Hx + M).$$

Substituting the last equality into the equation (3.5), we obtain

$$Fx^2 + \frac{1}{4G}(K + Hx + M)^2 - \frac{Hx+M}{2G}(K + Hx + M) + Lx + N - \rho(Kx + \eta) - \frac{K}{2G}(K + Hx + M) = 0.$$

Therefore the value function satisfies the following partial differential equation

$$\left(F - \frac{H^2}{4G}\right)x^2 - \left(\frac{HM}{2G} - L + \rho K + \frac{KH}{2G}\right)x - \frac{1}{2G}\left[M\left(K + \frac{M}{2}\right) + \frac{K^2}{2}\right] + N - \rho\eta = 0.$$

The following example can be solved by using the equation of optimality (2.4):

Example 3.3 *A special fuzzy differential equation based on a linear Liu's fuzzy control system*

$$dx_t = (\alpha x_t + \beta y_t + \eta)dt + (\gamma x_t + \delta y_t + \vartheta)dL_t$$

Where $\alpha, \beta, \gamma, \delta, \eta$ *and* ϑ *are deterministic real numbers.*

IV. AN APPLICATION TO FUZZY PRODUCTION INVENTORY CONTROL MODEL

In this section, we discuss a fuzzy production inventory planning model with fuzzy factors. We consider a factory producing a single homogeneous good and having a finished goods warehouse. In order to state the model we define the following notations:

x_t : the inventory level at time t (state variable),
y_t : the production rate at time t (control variable),
u_t : the constant demand rate at time t,
$\hat{x}$: the inventory goal level,
$\hat{y}$: the production goal level,
$x(0)$: initial inventory level,
q : the inventory holding cost coefficient; ($q > 0$),
r : the production cost coefficient; ($r > 0$),
ρ : the constant nonnegative discount rate; $\rho \geq 0$,
σ : the constant diffusion coefficient.

The inventory dynamics can be described as the fuzzy differential equation

$$dx_t = [y(t) - u(t)]dt + \sigma x_t dL_t, \quad x(0) = x, \quad (4.1)$$

ISBN: 978-988-18210-8-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

where L_t is a white noise which can be interpreted as sales returns or inventory spoilage. Note that x_t and y_t are fuzzy variables for each fixed time. The objective function of the model is:

$$J(x,y,t)=\frac{1}{2}E\left[\int_0^\infty e^{-\rho t}\left\{q(x_t-\hat{x})^2+r(y_t-y)^2\right\}dt\right]$$
(4.2)

The purpose of this objective function is to keep the inventory x as close as possible to its goal level $\hat{x}$, and also keep the production rate y as close as possible to its goal level $\hat{y}$. The quadratic $\frac{q}{2}(x_t-\hat{x})^2$ and $\frac{r}{2}(y_t-\hat{y})^2$ impose penalties for having either x or y not being close to its corresponding goal level.

Then fuzzy production inventory panning model is formulated as follows

$$V(x,y,t))=\min_y J(x,y,t) \qquad (4.3)$$

subject to (4.1).

It follows from the equation of optimality (2.4) that

$$\rho V(t,x)=\min_y\left\{\frac{1}{2}\left\{q(x_t-\hat{x})^2+r(y_t-y)^2\right\}+\frac{\partial V(t,x)}{\partial t}+\left[y(t)-u(t)\right]\frac{\partial V(t,x)}{\partial x}\right. =\min_y U(y) \qquad (4.4)$$

where $U(y)$ denotes the term in the braces. Setting $\frac{\partial U(y)}{\partial y}=0$, we obtain the necessary condition for optimality

$$y_t=\hat{y}-\frac{1}{r}\frac{\partial V(t,x)}{\partial x}. \qquad (4.5)$$

Substitute (4.5) to (4.4), we obtain the following partial differential equation

$$\rho V(t,x)=\frac{1}{2}q(x_t-\hat{x})^2+\frac{1}{2r}\left(\frac{\partial V(t,x)}{\partial x}\right)^2+\frac{\partial V(t,x)}{\partial t}+\left[\hat{y}-\frac{1}{r}\frac{\partial V(t,x)}{\partial x}-u(t)\right]\frac{\partial V(t,x)}{\partial x} \qquad (4.6)$$

From (4.5) we find $\frac{\partial V(t,x)}{\partial x}=r(\hat{y}-y_t)$. The solution of $\frac{\partial V(t,x)}{\partial x}=r(\hat{y}-y_t)$ is $V=r(\hat{y}-y_t)x+C$, where C is a constant and $\frac{\partial V(t,x)}{\partial t}=0$. Substituting these result in (4.6), we obtain

$$r\rho(\hat{y}-y_t)x+C\rho=$$
$$\frac{q}{2}x_t^2-q\hat{x}x_t+\frac{q}{2}x^2+\frac{r}{2}(\hat{y}-y_t)^2+r(y_t-u(t))(y-y_t).$$

Since $q>0$ and now matching the coefficients of the last polynomial in x, we require

$-q\hat{x}=r\rho(y-y_t)$ and

$C\rho=r(\hat{y}-y_t)\left\{\frac{1}{2}(y_t+y)-u(t)\right\}+\frac{q}{2}\hat{x}^2$. These give

$y_t^*=\hat{y}+\frac{q\hat{x}}{r\rho}$, and

$$C=\frac{r}{\rho}(\hat{y}-y_t)\left\{\frac{1}{2}(y_t+y)-u(t)\right\}+\frac{q}{2\rho}\hat{x}^2.$$

The optimal control is to set $y_t^*=\hat{y}+\frac{q\hat{x}}{r\rho}$ and the optimal value of the objective function is

$$V(x)=r(\hat{y}-y_t)\left[x+\frac{1}{\rho}\left\{\frac{1}{2}(y_t+y)-u(t)\right\}\right]+\frac{q}{2\rho}\hat{x}^2$$

where $x_t=x$.

V. CONCLUSION

A. Figures and Tables

We studied a fuzzy optimal control problem minimizing the expected value of discounted objective function for an infinite horizon subject to a fuzzy differential equation. We developed an equation of optimality in case of fuzzy optimal control problem. Following the equation of optimality we obtain an optimal feedback control in context of fuzzy linear quadratic control problem for fuzzy control system and we proved that the value function satisfied the partial differential equation associated with fuzzy linear quadratic control problem. It was also carried out with an example. We gave an application to fuzzy production inventory planning problem by using the equation of optimality.

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ISBN: 978-988-18210-8-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Measuring online Bank profit efficiency: A stochastic frontier analysis

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Abstract. This study proposed that Battese and Coelli (1995) [2] inefficiency model be applied as a framework in exploring the determinants of factors causing profit efficiency differential on banking industry in Bangladesh. Using stochastic frontier technique we examined the changes in the profit efficiency in accordance with Nationalized Commercial Banks, Islamic Banks, Foreign Banks and Private Banks and significant variations of efficiencies of banks for the period 2000 to 2007. The results showed that the profit inefficiency declined over the reference period and Translog Production Function is more preferable than Cobb-Douglas Production Function. Nationalized Commercial Banks are significantly inefficient and on the contrary ISBs, FBs, and PBs are efficient in producing profit and noteworthy. Year wise average efficiencies of banks from the profit efficiency model is 0.664 while group wise average profit efficiency is 0.639. Dhaka Bank is highly efficient with score 0.89 and AB Bank is lowest efficient with score 0.35.

1 Introduction

In recent years the structures of financial service industries are changing rapidly, it is of considerable interest to measure the efficiency of evolving institutions. Creditors and investors use such efficiency evaluations to judge past performance and current position of banks. Due to the growth of competition, bank management is interested in enhancing efficiency. Bank efficiency studies are of crucial importance for operational and academic proposes [6, 7].

Many studies evaluate a wide range aspect of banks efficiency, in different economies. Profit efficiency indicates how well a bank is predicted to perform in terms of profit relative to other banks in the same period for producing the same set of outputs. Despite the wide agreement on the relevance of profit efficiency analysis, the technical difficulties with the measurement and decomposition of profit inefficiency were the main reasons for the small number of empirical studies on banking profit efficiency. Both parametric and non-parametric techniques have been employed to compute efficiency scores, providing valuable insights not only for the academic research but also for regulation and management decisions [6]. Nevertheless, the majority of these studies limit their efficiency analysis to the cost side (*e. g.* [8, 23]), recent studies have given more attention to profit efficiency. Indeed, among the 130 studies surveyed by Berger and Humphrey [6], only fourteen of those studies employ a profit efficiency perspective. Some studies (e.g., [12]) provide banking profit efficiency scores for several European countries, including Portugal. So far, there is quite fair number of researches that studied banking efficiency in less developed countries. For example: Saudi [1], Bangladesh [24], Kuwait [19], Turkey [15, 16], Jordan [17], Bahrain [13], Malaysia [25], Pakistan [20], and U.A.E. [22].

The majority of studies investigating banking profit efficiency adopt a parametric approach following the prominent works of Berger and Mester [7], DeYoung and Nolle [11] and DeYoung and Hasan [10]. The few available studies that estimate profit frontier functions report efficiency levels that are much lower than cost efficiency levels, implying that the most important inefficiencies are on the revenue side (see [21]). To our knowledge, there is no study have focused exclusively on the profit efficiency of Bangladesh banking sector using stochastic frontier analysis. Therefore this study intends to reveal the overall performance of commercial banks with loan default and measuring bank efficiency in Bangladesh in the context to both productivity and profitability.

The Data Envelopment Analysis in measuring technical efficiency does not impose any assumptions about production functional form and does not take into account random error hence the efficiency estimates may be bias if the production process is largely characterized by stochastic elements. The present paper utilizes this Battese and Coelli [2] model, which is assumed to behave in a manner consistent with the stochastic frontier concept and it is used examine the profit efficiency level of banks in Bangladesh. The main focus of our study is to measure the bank profit efficiency in accordance with NBs (Nationalized Commercial Banks), ISs (Islamic Banks), FBs (Foreign Banks) and PBs (Private Banks) in Bangladesh. To determine the important factors causing profit efficiency differential on banking industry in Bangladesh is also our interest.

Bangladesh Banking Industry

The banking industries are the leaders of the financial-services industry. Bangladesh Bank is the Central Bank of Bangladesh and the chief regulatory authority in this financial sector. The banking system consists of four nationalized commercial Banks, around forty private commercial banks, nine foreign multinational banks and some specialized banks. The Nobel-prize winning Grameen Bank is a specialized micro-finance institution, which revolutionized the concept of micro-credit and contributed greatly towards poverty reduction and the empowerment of women in Bangladesh. Question arises how successfully the nationalized private commercial banks are serving the country, how far they have achieved their desired goals? It is commonly believed that the nationalized commercial banks are overcome with the vicious problem of corruption, inefficiency, loan default etc. although the private commercial banks are efficient in their commercial activities and solving the problem of loan default.

Private Banks are the highest growth sector due to the dismal performances of national/government banks. Foreign Banks are also the growth sector due to the performances of national commercial banks. Out of the specialized banks, two (Bangladesh Krishi Bank and Rajshahi Krishi Unnayan Bank) were created to meet the credit needs of the agricultural sector while the other two (Bangladesh Shilpa Bank (BSB) and Bangladesh Shilpa Rin Sangtha (BSRS)) are for extending term loans to the industrial sector. The Bangladesh banking sector relative to the size of its economy is comparatively larger than many economies of similar level of development and per capita income. The total size of the sector at 26.54% of GDP dominates the financial system, which is proportionately large for a country with a per capita income of only about US$540. The non-bank financial sector, including capital market institutions is only 3.22% of GDP, which is much smaller than the banking sector. While population per branch was 57,700 in 1972, it was 19,800 in 1991. In 2001 it again rose to 21,300, due to winding up of a number of branches and growth in population. Compared to India's 15,000 persons per branch in 2000, this indicates that the banking system in Bangladesh is a significant problem.

2 Methodology

2.1 Measurement of Variables

One of the crucial debated issues in the banking literature is output measurement. The present study adopts production approach to specify outputs and inputs of commercial banks. Accordingly, profits are defined as the outputs of commercial banks which are produced by using inputs like labor, capital and materials. All nominal values are converted to real by deflating with GDP deflator and all values are in their natural logarithms.

Data Set

We have used data for the period of 2001-2007 from 20 commercial banks of Bangladesh. Banks are grouped into four categories (i) National Banks (NBs), (ii) Islamic Banks (ISBs), (iii) Foreign Banks (FBs), (iv) Private Banks (PBs).

Most of the data are collected from the annual reports of the specific banks of Bangladesh and rest of them are collected from annual accounts of Scheduled Commercial Banks published by Bangladesh Bank, the central bank of Bangladesh. Deposits are measured as total deposits. Capital is measured as fixed assets (which includes premises, furniture and other fixed assets). Number of employees is measured as the total number of employees. Material is measured as the sum of expenditure on printing and stationeries, postage, telegrams and telephone etc. All nominal values are converted on real by deflating with GDP deflator and all values are in their natural logarithms.

Dependent Variable

Profit (Y): Banks and other financial institutions are simply businesses organized to maximize the profitability and that is why the performance of a commercial bank is measured by its profit efficiency. For this reason we have used profit as one of the most important outputs of a bank. In this study profit is equal to the pre-tax profit for all commercial banks. The nominal profit (output) values are deflated by respective consumer price index.

Independent Variables

Capital (X_1): Capital is the input variable representing the fixed assets of a bank in a year which also adds premises, furniture and fixture. Capital figures are deflated by capital price index.
Labor (X_2): Labor is one of the most important inputs to measure the productivity of a firm. Here labor means number of employee and is measured as the total number of employees which include officers, sub-ordinates and clerks.
Material (X_3): For the banking sector, material have been used as the sum of expenditure on printing and stationeries and postage, telegrams and telephones etc. Material prices are deflated by non-food price index.
Time (X_4): To find the productive efficiency of a bank over time we have used time as the input variable. In this study we have collected data of seven years from 2001 to 2007 and used 1 for year 2001, 2 for 2002 and so on.

Explanatory Variables
Time (Z_1): Time is also used in this study as influencing variable.
Total Asset (Z_2): Total asset used as the influencing variable and is the sum of all assets and their book value.
Herfindahl-Hirschman Index (HHI) (Z_3): The Herfindahl-Hirschman index takes into accounts both the relative size and number of banks in the banking

sector. Mathematically, HHI is described as follow: $HHI = \sum_{i=1}^{N} S_i^2$ where N is the number of banks and S_i is share of the i^{th} bank. HHI is known as measure of competition which is measured as the sum of squared of the output share of each bank in the output of considered total banks in Bangladesh.

NB, ISB, FB, and PB are bank group specific dummies for National Bank, Islamic Bank, Foreign Bank, and Private Bank respectively. The dummy variables can take either 1 or 0 depending on data availability or not respectively.

2.2 A Theoretical Stochastic Frontier Model

The present study we used the approach proposed by Battese and Coelli [2] which explicitly account for statistical noise. The specification of the model may be expressed as:

$Y_{it} = \beta X_{it} + (V_{it} - U_{it}),\ i = 1, 2, ..., N;\ t = 1, 2, ..., T$ ....(1)

where Y_{it} is the (logarithm of) output of the i^{th} bank in t^{th} period; X_{it} is a vector of input quantities; β_i's are unknown parameters to be estimated; V_{it}'s random variables which are assumed to be i.i.d., $N(0, \sigma_v^2)$ and independent of U_{it} ; U_{it}'s are non-negative random variables which are assumed to account for technical inefficiency in output and to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution; where $U_{it} = Z_{it}\delta$; where; Z_{it} is a $(1 \times p)$ vector of variables which may influence the inefficiency of bank industry and δ is a $(p \times 1)$ vector of parameters to be estimated. The parameterization from Battese and Corra [4] are used replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$.

The Technical inefficiency effect U_{it} in the stochastic frontier model is specified as follows;

$U_{it} = Z_{it}\delta + W_{it}$ ....(2),

where, the random variable, W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_{it}\delta$. Parameters of the stochastic frontier given by equation (1) and inefficiency model given by equation (2) are simultaneously estimated by using maximum likelihood estimation [3]. After obtaining the estimates of U_{it} the technical efficiency of the i-th bank industry at t-th time period is given by:

$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it})$ ....(3).

2.3 A Stochastic Frontier Model of Profit Inefficiency

The functional form of the profit Translog stochastic frontier production model is defined as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln M_{it} + \beta_3 \ln L_{it} + \beta_4 T$$
$$+ \tfrac{1}{2}\left(\beta_{11} \ln K_{it}^{\;2} + \beta_{22} \ln M_{it}^{\;2} + \beta_{33} \ln L_{it}^{\;2} + \beta_{44} T^2\right)$$
$$+\beta_{12} \ln K_{it} * \ln M_{it} + \beta_{13} \ln K_{it} * \ln L_{it} + \beta_{14} \ln K_{it} * T + \beta_{23} \ln M_{it} * \ln L_{it}$$
$$+\beta_{24} \ln M_{it} * T + \beta_{34} \ln L_{it} * T + V_{it} - U_{it} \text{.........................}(4),$$

where, **the subscripts i and t represent the i-th bank industry and the t-th year of observation, respectively;** $i = 1, 2, ..., 20$; $t = 1, 2, ..., 7$;

Y_{it} denotes the output variables (profit) of the ith bank industry in the t-th period in values (taka);

K_{it} denotes capital (fixed assets of a bank in a year which also adds premises, furniture and fixture) of i-th bank industry in the t-th period;

M_{it} represents materials (the sum of expenditure **on printing and stationeries and postage, telegrams and telephones etc)** of i-th bank industry in the t-th period;

L_{it} represents labor (the total number of employees which include officers, sub-ordinates and clerks) of i-th bank industry in the t-th period;

T represents year of observation; **"ln" refers to the natural logarithm.**

Further, the bank industry specific inefficiency is considered as a function of some explanatory variables and the inefficiency effects model is defined as:

$$U_{it} = \delta_0 + \delta_1 T + \delta_2 TA + \delta_3 HI + \delta_4 NB + \delta_5 ISB + \delta_6 FB + \delta_7 PB + W_{it} \text{ ....}(5),$$

where δ_0 is the intercept term and δ_j $(j = 1, 2, 3, 4, 5, 6, 7)$ is the parameter for the j-th explanatory variable, T=Year of observation, TA=Total Assets, HHI= **Herfindahl-Hirschman** Index, **NB is the dummy variable for Nationalized Commercial Banks: NB=1 if an observation involves a Nationalized Commercial Bank, zero otherwise; ISB is the dummy variable for Islamic banks: ISB=1 if an observation involves an Islamic bank, zero otherwise; FB is dummy variable for Foreign Banks: FB=1 if an observation involves a Foreign Bank, zero otherwise; PB is dummy variable for Private Banks: PB=1 if an observation involves a Private Bank, zero otherwise;**

2.4 Likelihood Ratio Tests and Hypothesis

The following hypotheses requires testing with the generalized likelihood ratio test statistic is defined by

$$\lambda = -2\left\{\ln\left[L(H_0)/L(H_1)\right]\right\} = -2\left\{\ln\left[L(H_0)\right] - \ln\left[L(H_1)\right]\right\} \cdots\cdots (6)$$

where $L(H_0)$ and $L(H_1)$ are the value of the likelihood function for the profit frontier model under the null and alternative hypothesis. Under the null hypothesis, this test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value [26]. These are obtained by using the values of the log–likelihood functions for the banking industries and the stochastic frontier production function.

The following null hypotheses will be tested:

$H_0 : \beta_{ij} = 0$, the null hypothesis that identifies an appropriate functional form either the restrictive Cobb-Douglas or Translog production function. It specifies that the second-order coefficients of the stochastic frontier production function are simultaneously zero.

$H_0 : \gamma = 0$, the null hypothesis specifies that the technical inefficiency effects in banks are zero. This is rejected in favor of the presence of inefficiency effects. Here γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiency and defined by $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier models by using the computer program frontier version 4.1 developed by Coelli [9]. If the null hypothesis is accepted this would indicate that $\sigma_u{}^2$ is zero and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square (OLS).

Further $H_0 : \eta = 0$, the null hypothesis that the technical inefficiency effects are time invariant i.e., there is no change in the technical inefficiency effects over time. If the null hypothesis is true, the generalized likelihood ratio statistic λ is asymptotically distributed as a chi-square (or mixed chi-square) random variable.

3 Results and Discussion

In this section Ordinary Least Square Estimates (OLS) and Maximum Likelihood Estimates (MLE) of the parameters have been reported in the context of bank specific profit efficiency of Bangladesh followed by Translog stochastic frontier model. The ordinary least square estimates of parameters are obtained by grid search in the first step and then these estimates are used to

estimate the maximum likelihood estimates of the parameters treated as the profit frontier estimates of Translog stochastic frontier production model.
The ordinary least squared estimates of profit efficiency model are presented in the table 1. First order coefficients of the parameters of profit efficiency model are statistically significant in case of OLS estimation at different level but some second order variables are statistically insignificant. In OLS estimates all first order parameters in profit model show positive sign. All input variables except some second order variables are indispensable contributors to boost the bank profit efficiency in Bangladesh.
The maximum likelihood estimates (MLE) of parameters in the profit efficiency model along with inefficiency estimates have been reported in the table 2. The maximum likelihood estimates of the coefficients of capital and material are found to be significant with the values -0.696 and 0.887 respectively while the coefficients of labor and time have been found insignificant with 0.062 and 0.053 respectively. The insignificance of the estimated labor coefficients is not surprising given that most banks may be still overstaffed even after many years of reforms. The most expected result has been observed in inefficiency effects model of profit efficiency and the result for the estimated coefficient of time with -0.370 indicated that day by day the level of efficiency is being increased. It is observed that time, total assets, Herfindahl-Hirschman Index are having negatively significant in this model.
In the inefficiency effects model, a positive coefficient value increases the level of inefficiency and vice-versa. Hence from the result it is reported that time, total assets and Herfindahl-Hirschman Index are increasingly decreasing the level of inefficiency. Other explanatory variables in the inefficiency model are the dummies of four banks group taking value 0 or 1. From the coefficients of these variables it is clear that Foreign Banks and Private Banks are more efficient in profits making than that of their counterparts Nationalized Commercial Banks and Islamic Banks. The negative coefficient of time indicates that the profit level tends to increase by 1.37 percent per year over the time period.
The estimated results of the profit efficiency model are reported in the figures 1, 2 and 3 according to group wise, year wise and bank wise respectively. It is observed that on an average, Bangladeshi banks are 66.4 percent efficient in profits making services relative to the best performing bank during the study period. In case of profit efficiency, foreign banks are most efficient (68.8 percent) along with private banks (68.7 percent). From this study it is revealed that Government owned banks are least efficient that increase profits level with 58.4 percent. During the period 2001 to 2004, profit efficiency of nationalized commercial banks was almost stable and it was around 45.8 percent but in the following year efficiency scores increase dramatically and it becomes almost doubled with 87.5 percent. Again the efficiency of NBs decreases in the years

2006 and 2007. On the other hand private banks are very consistent in this regard.

Table 1 OLS Estimates of Translog Stochastic Frontier Production Function: Profits Frontier Estimates

Variables	Parameters	Coefficients	S.E	t-value
Constant	β_0	1.692^{**}	1.693	1.693
Capital	β_1	0.616^{***}	-1.398	-1.398
Material	β_2	0.873^{*}	4.538	4.538
Labor	β_3	0.466^{*}	-2.371	-2.371
Time	β_4	0.179^{**}	1.942	1.942
Capital*Capital	β_{11}	$0.212^{@}$	-0.029	-0.029
Material*Material	β_{22}	0.355^{**}	-2.303	-2.303
Labor*Labor	β_{33}	$0.049^{@}$	0.624	0.624
Time*Time	β_{44}	$0.023^{@}$	0.754	0.754
Capital*Material	β_{12}	$0.212^{@}$	0.442	0.442
Capital*Labor	β_{13}	$0.107^{@}$	1.105	1.105
Capital*Time	β_{14}	$0.044^{@}$	-0.803	-0.803
Material*Labor	β_{23}	$0.149^{@}$	-0.214	-0.214
Material*Time	β_{24}	0.064^{**}	-2.129	-2.129
Labor*Time	β_{34}	0.030^{*}	2.323	2.323
Sigma-squared	0.25333467			
Log likelihood function	-94.605314			

*, **, *** Significance level at 1 %, 5 %, 10% consecutively

@ means insignificant, S.E = Standard Error

Table 2 Maximum-likelihood Estimates of Translog Production Function: Profit Frontier Estimates

Variables	Parameters	Coefficients	S.E	t-value
Constant	β_0	5.106^{*}	0.724	7.051
Capital	β_1	-0.696^{*}	0.299	-2.328
Material	β_2	0.887^{*}	0.147	6.031
Labor	β_3	$0.062^{@}$	0.121	0.509
Time	β_4	$0.053^{@}$	0.084	0.633
Capital*Capital	β_{11}	0.081^{*}	0.011	7.058
Material*Material	β_{22}	-0.514^{*}	0.151	-3.392
Labor*Labor	β_{33}	0.036^{***}	0.023	1.541
Time*Time	β_{44}	0.029^{*}	0.005	5.831
Capital*Material	β_{12}	0.257^{*}	0.103	2.496
Capital*Labor	β_{13}	-0.048^{*}	0.010	-4.994
Capital*Time	β_{14}	-0.063^{**}	0.028	-2.256
Material*Labor	β_{23}	$-0.010^{@}$	0.037	-0.256
Material*Time	β_{24}	$0.010^{@}$	0.034	0.295
Labor*Time	β_{34}	0.036^{**}	0.018	1.977

*, **, *** Significance level at 1 %, 5 %, 10% consecutively

@ means insignificant, S.E = Standard Error

Determinants of Inefficiency				
Variables	Parameters	Coefficients	S.E	t-value
Constant	δ_0	2.493*	0.967	2.578
Time	δ_1	-0.370*	0.065	-5.708
Total Assets	δ_2	-0.192***	0.120	-1.604
Herfindahl-Hirschman Index	δ_3	-0.058@	0.213	-0.272
NB Dummy	δ_4	1.404**	0.788	1.782
ISB Dummy	δ_6	1.687*	0.509	3.311
FB Dummy	δ_7	-0.440@	0.829	-0.530
PB Dummy	δ_8	-0.158@	0.513	-0.308
Sigma-squared		0.860*	0.103	8.312
Gamma		.99999*	0.00021	28454.734

*,**,*** Significance level at 1%, 5%, 10% consecutively

@ means insignificant, S.E = Standard Error

Table 3 Generalized Likelihood-Ratio Test of Hypothesis of the Stochastic Profit Frontier Production Model

NULL HYPOTHESIS	LOG-LIKELIHOOD FUNCTION	TEST STATISTIC λ	CRITICAL VALUE*	DECISION
$H_0 : \gamma = 0$	-94.59	107.77	3.38	Reject H_0
$H_0 : \beta_{ij} = 0$	-12.21	24.39	19.35	Reject H_0
$H_0 : \eta = 0$	-40.65	81.29	3.38	Reject H_0

Notes: All critical values are at 5% level of significance.
*The critical value are obtained from table of Kodde and Palm [18]. The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution , because the restriction defines a point on the boundary of parameter space.

The year wise average profit efficiency of 20 banks in Bangladesh has been described the figure 2. From this investigation we observed that the highest average profits efficiency was in 2005 and the inefficiency score was 76.5 percent and in 2001 the profit efficiency was 58.4 percent. In 2007 the profit efficiency increses by 26.36 percent dramatically from 2001. From the figure 2 the over all situation of banks' performance is to be clearly understood. Time has an important affect in reducing profit inefficiency. In case of profit efficiency model the efficiency has gradualy increased.

Bank wise profits efficiency of 20 banks shows a more clear perception about the performance of an individual bank and the individual profit efficiency has been portrayed in the figure 3. The most efficient banks during the study period

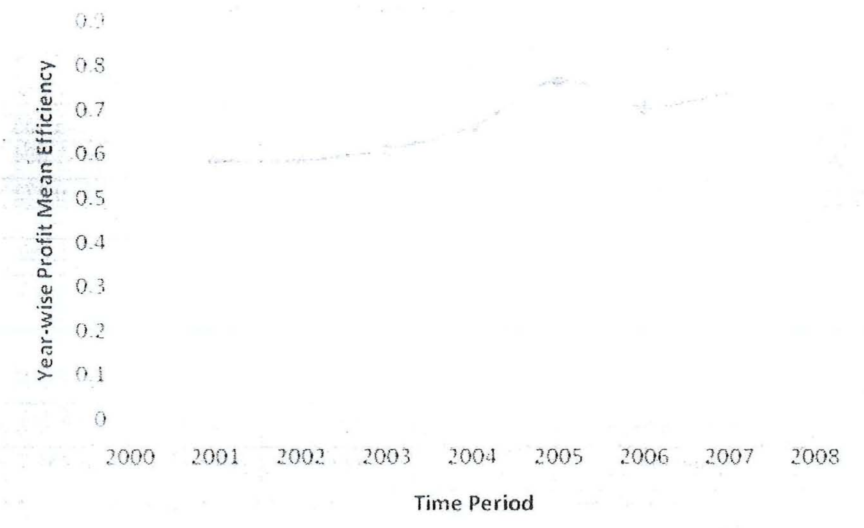

Figure1 Year-wise average profit efficiency over time

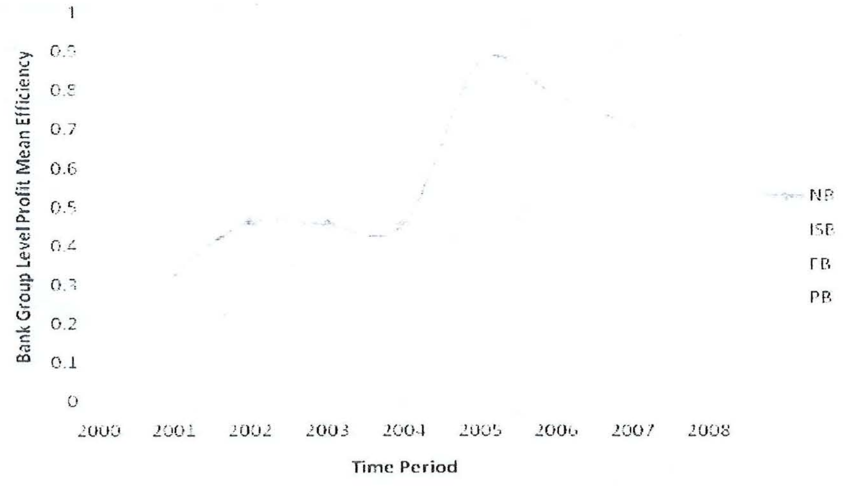

Figure 2 Bank group level profit mean efficiency over time

Table 4 Profit Efficiency of Banks in Bangladesh

S.N.	Bank's Name	2001	2002	2003	2004	2005	2006	2007	Mean Effi.
1	Sonali Bank	0.220	0.382	0.194	0.291	0.987	0.579	0.479	0.447
2	Janata Bank	0.455	0.544	0.718	0.625	0.762	0.993	0.947	0.721
3	Islami Bank	0.266	0.397	0.293	0.468	0.686	0.583	0.797	0.499
4	Shahajal Islami Bank	0.589	0.584	0.599	0.126	0.682	0.867	0.989	0.634
5	Al Arafah Bank	0.846	0.332	0.570	0.594	0.747	0.926	0.661	0.668
6	Bank Asia	0.340	0.542	0.813	0.991	0.978	0.851	0.894	0.773
7	The city Bank	0.357	0.467	0.586	0.720	0.817	0.673	0.602	0.603
8	National Bank	0.607	0.635	0.314	0.318	0.261	0.446	0.443	0.432
9	Prime Bank	0.978	0.838	0.949	0.891	0.966	0.726	0.650	0.857
10	Uttara Bank	0.999	0.812	0.633	0.625	0.724	0.462	0.436	0.670
11	One Bank	0.282	0.477	0.437	0.947	0.865	0.967	0.983	0.708
12	UCB Bank	0.605	0.504	0.713	0.845	0.923	0.778	0.906	0.753
13	Pubali Bank	0.809	0.801	0.512	0.331	0.595	0.543	0.692	0.612
14	Priemer Bank	0.388	0.543	0.635	0.987	0.771	0.620	0.515	0.637
15	Mutual Bank	0.360	0.560	0.933	0.922	0.888	0.797	0.608	0.724
16	South East Bank	0.991	0.843	0.756	0.749	0.895	0.895	1.000	0.876
17	Eastern Bank	0.961	0.885	0.935	0.944	0.756	0.698	0.690	0.838
18	AB Bank	0.112	0.113	0.166	0.303	0.511	0.340	0.933	0.354
19	Dhaka Bank	0.994	0.965	0.926	0.932	0.819	0.725	0.935	0.899
20	DBBI	0.525	0.491	0.503	0.602	0.665	0.624	0.606	0.574

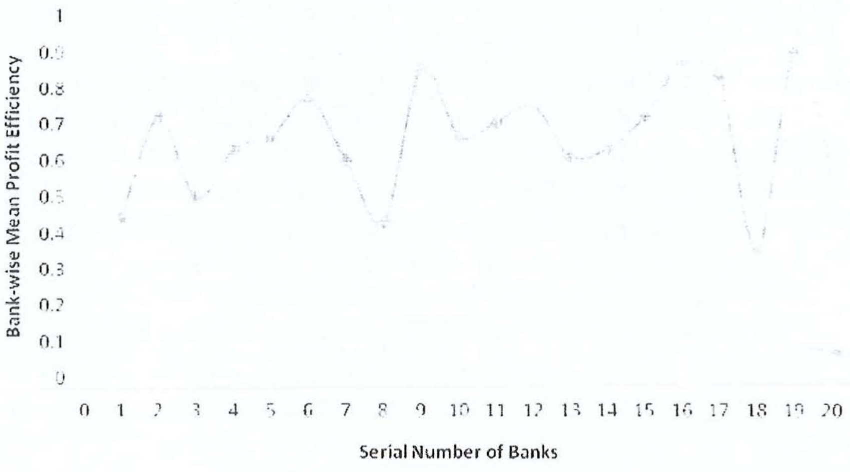

Figure 3 Profit mean efficiency by serial number of banks

are Dhaka bank (with 89.9 percent), South East bank (with 87.6 percent), Prime bank (with 85.7 percent), Eastern bank (with 83.8 percent), and Bank Asia (with 77.3 percent). On the contrary, the most inefficient banks during the data period are AB bank (with 35.4 percent), National bank (with 43.2 percent), Sonali bank (with 44.7 percent), and DBBl with 57.4 percent).

At the beginning of the study period Uttara bank was most efficient in profits making but it could not retain its position at the end of the period. Opposite scenario has been observed in case of Islamic banks and during 2001 to 2004 Islamic banks are comparatively less efficient to raise profits level but at the end of the race their growth surprisingly increased. In 2001-2004 the average profit efficiency was around 45 percent and in 2006-2007 it is around 98 percent. Hence Islamic banking system has been enjoying considerable profits efficiency for two years according to this study. Moreover, foreign banks are very much efficient in producing profits making as they are at the top position which is really an alarming threat to the Nationalized Commercial banks (NBs) because reverse situation has been taken place to the NBs.

All NBs are inefficient to boost up the profitability. From the inefficiency model of the profit model we have noticed that total assets are highly insignificant. Therefore the conclusion is that Nationalized Commercial Banks should properly handle their total assets make a standard solution to still existing overstaffed even after many years of reforms.

3.1 Hypothesis Tests of Profit Efficiency Model

The results of various hypothesis tests of the profit efficiency model are presented in table 3. The all hypothesis tests are obtained using the generalized likelihood-ratio statistic (6).

The first null hypothesis is $H_0 : \gamma = 0$,which specify that there is no technical inefficiency effect in the profit efficiency model. The hypothesis is rejected so we can conclude that there is a technical inefficiency effect in the model.

The second null hypothesis is $H_0 : \beta_{ij} = 0$, which specifies that Cobb-Douglas Production Function is more preferable than Translog Production Function. From the result it is observed that the null hypothesis is strappingly rejected and Translog Production Function is more favorable.

The third null hypothesis is $H_0 : \eta = 0$, which specifies that the technical inefficiency effect does not vary considerably over time in the profit efficiency model. The null hypothesis is rejected signifying that the technical inefficiency effect differs significantly.

4 Conclusion

This study sets out to provide estimates of bank profit efficiency and to compare efficiency estimates for NBs (National Banks), ISBs (Islamic Banks), FBs (Foreign Banks), and PBs (Private Banks) of Bangladesh banking industries using stochastic frontier analysis. We compared the profit (in) efficiencies of 20 Commercial Banks group wise, year wise and specific bank wise over time period.

The most important results are summarized below:

First, we analyzed the Translog Stochastic Frontier Production Function with distributional assumptions for profit efficiency model and the presence of one-sided error component is justified by the LR test individually, which is highly significant for this model. The estimates of variance ratios ($\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$) of profit efficiency model is 0.999 indicate that the inefficiency element U_{it} is stochastic. We found that the profit inefficiency has declined over the reference period and Translog Production Function is more preferable than Cobb-Douglas Production Function.

Second, The most expected result has been observed in inefficiency model of profit function and the result is the estimated coefficient of time with -0.370 indicating that day by day the level of efficiency is being increased. From the estimated coefficients of inefficiency model it is seen that time, total assets, Herfindahl-Hirschman Index are found significant with negative values represented decreasing the level of inefficiency.

Third, the estimated year wise average efficiencies of the sample banks from the profit model is 0.664 while group wise average technical efficiencies is 0.639. In case of profit efficiency, foreign banks are most efficient (68.8 percent) along with private banks (68.7 percent). From this study it is revealed that Government owned banks are least efficient that increase profit level with 58.4 percent. During the years 2001 to 2004 profits efficiency of nationalized commercial banks were almost stable and it was around 45.8 percent but in the following year efficiency scores increase dramatically and it becomes doubled with 87.5 percent. Again the efficiency of NBs decreases in the years 2006 and 2007. On the other hand private banks are very consistent in this regard. In terms of profit model, Dhaka Bank is highly efficient with score 0.89 and AB Bank is lowest efficient with score 0.35 according to the sample data.

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