Empirical Estimation of Technical and Scale Efficiency in Indian City Gas Distribution (CGD) Entities Using DEA

** T. Nandakumar*
*** Sandeep Chouhan*

Abstract

This paper empirically examined the technical and scale efficiency of 14 entities of Indian city gas distribution (CGD) entities using the data development analysis. The efficiency score thus obtained was used for ranking the entities. This study also discovered, on an average, that the entities which had legacy and well entrenched infrastructure performed more efficiently than newer entities. This study also pointed out that most of the firms, which were new entrants and small in size, were operating under increasing return to scale. Currently, the Indian regulatory authorities follow the traditional approach of rate of return method for the promotion of CGD entities and benchmarking of these utilities through efficient measurement. The present study shall help regulators to monitor their performance for reducing the information asymmetry between the regulator and regulated companies.

Keywords : **data envelopment analysis, technical and scale efficiency, PNGRP, Indian CGD entities**

JEL Classification: L11, L23, L95

Paper Submission Date : July 28, 2015 ; Paper sent back for Revision : January 18, 2016 ; Paper Acceptance Date : April 8, 2016

Compared to conventional fossil fuels, natural gas is an environmentally benign and clean fuel in terms of emission norms. It is an eco-friendly as well as cost effective fuel as compared to other industrial fuels like fuel oil. The desired properties like easy transport and safe handling make natural gas an important fuel in the energy mix of countries. In the Indian context, the share of natural gas in the country's energy basket was nearly 13% in 2011 and is expected to reach a level of 20% by 2020. Power and fertilizer sectors remain the two biggest contributors to natural gas demand in India and continue to account for more than 55% of gas consumption (Corbeau, 2010). Another important segment that drives natural gas demand is city gas distribution (CGD) comprising of transport, domestic, and industrial consumers.

Natural gas is used as compressed natural gas (CNG) in the transport sector as a substitute for petrol and diesel. In the domestic and industrial front, natural gas is supplied as piped natural gas (PNG) as a replacement for LPG and fuel oil. For distribution of PNG to consumers, CGD companies set up a network of steel and medium density polyethylene pipelines across their geographical areas (GAs) that transport the gas from their city gas stations (where gas is received from the supplier) to the consumer ; for retailing CNG, companies set up dispensers either at their own exclusive stations or at the fuel pumps of oil marketing companies (OMCs). The

* *Senior Manager (Chemical),* GAIL (India) Ltd., 8th Floor, GAIL Jubilee Tower, Plot No : B-35&36, Sector-1, Noida-201 301 & *Ph.D. Scholar,* Indian Institute of Foreign Trade (IIFT), New Delhi. E-mail : nandakumar@gail.co.in
** *Manager (Marketing),* GAIL (India) Ltd., 16, Bhikaji Cama Place , R. K Puram, New Delhi-110 066.

Government of India (GoI) formed the oil & gas downstream regulator Petroleum and Natural Gas Regulatory Board (PNGRB) in 2007 for the regulation of CGD business. This initiative led to an orderly development of CGD business and increased competition in this segment.

While the gas demand for the CGD segment was about 18 mmscmd in 2012-13, the actual supply was about 14 mmscmd. The demand in the CGD sector is expected to witness a robust growth in the coming years and is expected to reach a level of 86 mmscmd by 2030. The biggest challenge for the segment is the shortage of domestic gas. Declining gas production in the country has led CGD operators to increasingly rely on costly imports of LNG and the CGD sector consumed nearly 18% of LNG in 2013. However, operators have observed consumers' willingness to pay for the high-priced LNG and have thus been able to operate successfully, although their profit margins have reduced. These challenges bring about further operational issues of CGD organizations involving effective utilization of existing assets and improving the trunk line and last mile connectivity of networks and ensuring network safety and integrity, leakage detection, inefficient metering, and so forth. For more effective operations, CGD companies have to deploy world-class technologies and best practices.

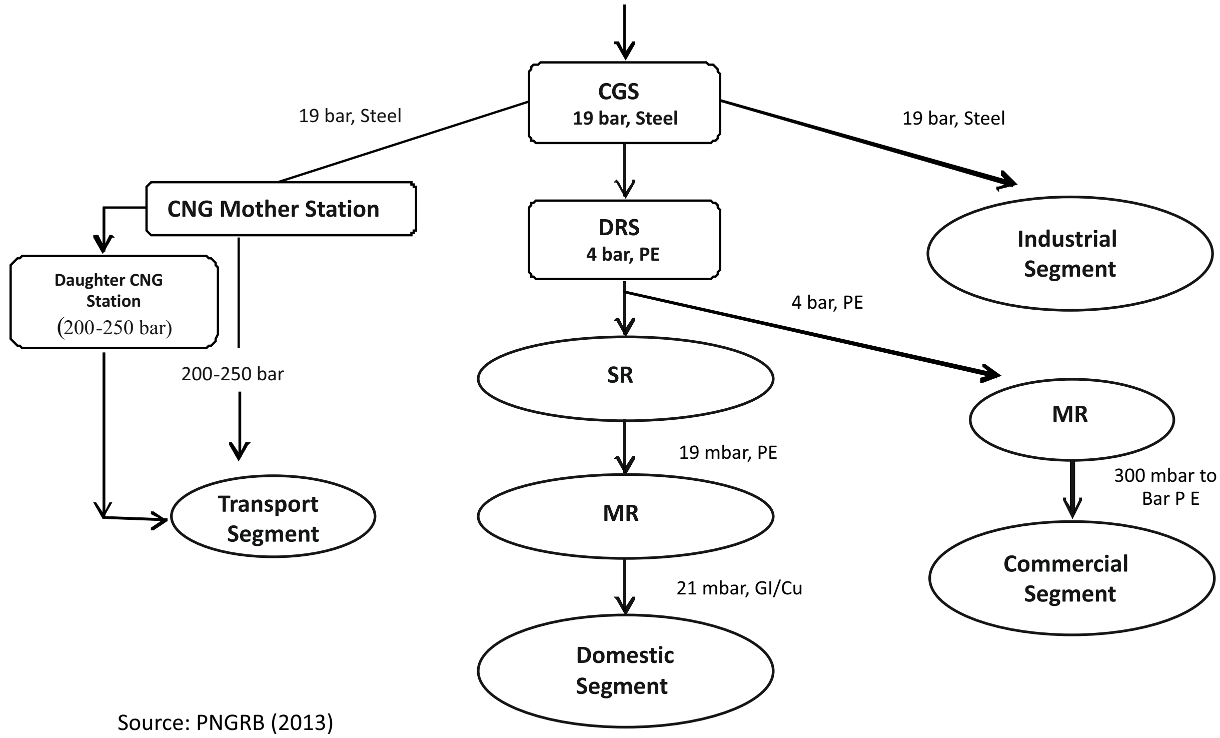
The Government of India (GoI) formed the oil and gas downstream regulator PNGRB in 2007 for the regulation of the CGD business. Currently, Indian regulators are following the traditional rate of return concept and this initiative led to an orderly development of CGD business and increased competition in this segment. Benchmarking of these utilities shall help the regulator to monitor their performance and thereby reduce the information asymmetry between the regulator and regulated companies. This paper aims to measure the relative efficiency of selected Indian CGD entities using the non-parametric data envelopment analysis (DEA).

City Gas Distribution in India

The Indian natural gas market is one of the fastest growing markets in the world. It was forecasted that the demand for natural gas shall increase at 5.4% per annum during 2007 to 2030 to reach a demand level of 132 BCM by 2030 (Corbeau, 2010). In the year 2014, natural gas contributed to nearly 10% in Indian primary energy supply, and in the same year, the total natural gas consumption stood at 50.6 BCM. The consumption pattern of natural gas in India is led by the power and fertilizer sector, followed by petrochemical, refineries, and city gas distribution. Natural gas use in India started to grow from 1970 after the huge gas find in Bombay High. Gas Authority of India (GAIL) was formed in 1984 to lay and manage cross-country pipelines for linking the natural gas fields to the big industrial consumers in the fertilizer and power sectors. The first major cross country pipeline - HBJ (Hazira--Vijaipur--Jagdishpur) pipeline was constructed in the year 1987-89. Currently, GAIL is managing a network of nearly 11,000 km of pipeline with an installed capacity of 210 mmscmd with current capacity utilization of around 50%. In 2006, the monopoly of GAIL to lay, transport, and market natural gas was abolished. The downstream regulator PNGRB formed for this purpose determines the access code for third-party access for one-third of the capacity and sets the tariffs of transportation for third parties.

Even though retail gas supply existed in India since 1880s in the form of coal gas supply by Kolkata Gas Company and Bombay Gas Company, the structured development of CGD sector in India happened in 1980s as GAIL initiated techno-economic feasibility studies for natural gas distribution in the metro cities of Mumbai and Delhi through Sofragaz and British Gas, respectively. Based on the encouraging results of these studies, Mahanagar Gas Limited (MGL), a joint venture company of Gas Authority of India Limited (GAIL), British Gas, and Government of Maharashtra was incorporated in May 1995 for the supply and distribution of natural gas (NG) to domestic, commercial, small industrial consumers, and compressed natural gas (CNG) to vehicular consumers in Mumbai through its integrated gas pipeline network. Similarly, Indraprastha Gas Limited (IGL), a JV of GAIL and Bharat Petroleum Corporation Limited (BPCL), was incorporated in December 1998 for

Figure 1. A Typical CGD Network



Source: PNGRB (2013)

Table 1. Predefined Parameters and Criteria for Selection of CGD Bidders

Parameters	Criteria	% Weightage
Network Tariff	Lowness of Present Value (PV) of Network Tariff quoted in INR/MMBTU for 6th year to 25th Year	70%
Compression Charges	Lowness of Present Value (PV) of CNG compression charge quoted in INR/kgs for 6th year to 25th Year	30%

Source: Petroleum and Natural Gas Regulatory Board. (2008). G.S.R 197(E) : PNGRB Determination of network tariff for city or local natural gas distribution networks and compression charge for CNG regulations.

developing a distribution network for residential, transport, and commercial consumers in Delhi. Further impetus to the CGD expansion was provided by the directive of Hon'ble Supreme Court of India in 2003 to expand the clean fuel network to 11 cities apart from Delhi and Mumbai. The typical CGD network (Figure 1) has high pressure lines made of steel and medium pressure and low pressure lines made of polyethylene (HDPE) and medium-density poly ethylene (MDPE). The network receives the gas from the trunk line at city gas station and further distributes the gas as PNG and CNG to the end consumers.

Current Regulatory Framework for CGD

In 2007, the GOI notified the downstream regulator, the Petroleum and Natural Gas Regulatory Board (PNGRB) which has, among other mandates in the hydrocarbon sector, the mandate of regulating the CGD business. PNGRB, under the relevant regulations of authorizing entities to lay, build, operate, or expand city or local natural gas distribution networks provides a legal framework for uniform development of CGD networks and calls for expression of interests (EOI) on competitive bidding basis across a geographical area (GA). The Table 1 provides the predefined parameters and criteria for selection of CGD bidders apart from minimum qualifying technical and financial criteria.

Moreover, PNGRP has prescribed that the variation in unit network tariff as well as the compression charges between any 2 consecutive years should not be more than 10%. PNGRP has provided network exclusivity for a period of 25 years for the winning bidders considering an economic life of 25 years for whole pipeline networks, and marketing exclusivity is applicable for a period of 5 years for new bidders and 3 years for existing bidders. However, this exclusivity clause will be revoked by the regulator if the entity does not meet the assured indicated minimum work programme on minimum number of domestic connections and laying of steel pipe networks. Beyond the exclusivity period, the network has to be opened for access to third party on payment of network tariff.

The tariff is regulated and determined by PNGRB guided by the principle of promoting healthy competition, improving efficiency of connected infrastructures such as pumps, compressors, and economic utilization of resources, good performances, and optimum investments.

The reference tariff rate is arrived at based on cost of service, internal rate of return, net present value, or alternate mode of transport. Thus, the main economic objective of tariff setting is to protect the interests of consumers, and at the same time, recover the cost of transport in a reasonable manner. The unit rates of network tariff for all customers and compression charges for CNG shall be calculated based on "discounted cash flow" considering a reasonable rate of return which is the rate of return on capital employed equal to 14% post tax considering the rate of return on long term risk free government securities and the capital employed in creation and operations of CGD infrastructure. The infrastructure in the CGD network should be adequate to maintain an uninterrupted flow of natural gas in the pipelines and also be able to maintain supplies at an adequate pressure to online CNG stations. Thus, it is a classic case of cost of service regulations wherein all eligible expenses are taken into account for calculating a required rate of return.

After the formation of downstream regulator PNGRB in 2007, the CGD sector witnessed an orderly development of networks across many cities and geographical areas (GA). Twenty three CGD entities were operating across 52 GAs while active construction was going on in 20 GAs in 2012-13. The CGD network in India was 34,073 km in 2012-13, with an incremental growth of 37% over 2011-12. These networks cover 90 cities across 52 geographical areas. The total number of CNG stations in CGD network was 913 as of March 2013, an increase of nearly 17% from March 2012.

Literature Review

Earlier studies on efficiency measurement of natural gas / CGD utilities were carried out in Europe and USA to benchmark their performance for regulatory purposes. There are many econometric methods or linear programming techniques available for measuring the relative efficiency for benchmarking studies. The most suitable method for measuring efficiency is the frontier analysis. The frontier approach may be based on parametric or non-parametric techniques like stochastic frontier analysis (SFA) or data envelopment analysis (DEA). Among these, DEA is one of the most widely used techniques for efficiency estimation and ranking of decision making units as it does not require cost or production function for construction of efficient frontiers (Farrell, 1957). Further, the index approach is also employed in performance management of gas utilities to measure partial or total factor productivity. Some of the related literatures are discussed below.

Kim, Lee, Park, and Kim (1999) employed multilateral Tornqvist productivity analysis, managerial index system analysis, and non-parametric efficiency analysis for studying the performance of the natural gas industry across countries. Rossi (2001) measured the technical change and efficiency of Argentinian gas utilities using SFA and Malmquist productivity index for estimating the catching up effect and frontier shift post liberalization of the gas sector. Sadjadi, Omrani, Abdollahzadeh, Alinaghian, and Mohammadi (2011) developed and applied robust super-efficient DEA model for ranking different gas companies in Iran. This improved DEA method can handle the uncertainty in inputs and output data as encountered in the real world situation with high reliability. Another version of DEA, the bootstrapped DEA technique was employed by Hawdon (2003) to measure the efficiency of natural gas companies across 33 countries. Erbetta and Rappuoli (2003) estimated the optimum scale and technical efficiency of Italian gas distribution industry using DEA and more recently, Storto (2014) utilized various DEA models to study operational efficiency of 32 gas distributors in Italy and proved that technical efficiency and economy of scale mattered for these utilities.

Jamasb, Newbery, Pollitt, and Triebs (2007) in their report to The Council of European Energy Regulators (CEER) recommended benchmarking of gas utilities using the three most widely adopted frontier-based benchmarking methods; DEA, SFA, and corrected ordinary least square (COLS) methods. Jamasb, Pollitt, and Triebs (2008) carried out DEA and Malmquist productivity studies for a panel of USA interstate natural gas utilities to measure the impact of cost plus regulations and derived valuable recommendations for European regulators. Zorić, Hrovatin, and Scarsi (2009) had studied benchmarking studies of gas utilities across Slovenia, The Netherlands, and the UK by conducting DEA studies and concluded that benchmarking can be employed as a useful complementary instrument for monitoring utility performance. Maria, Cullmann, and Neumann (2009) employed the PCA-DEA methodology for the estimation of efficiency of U.S. natural gas transport utilities and concluded that for a large number of original variables, the model is suitable and the discriminatory power of the model is not reduced. Ertürk (2009) carried out efficiencies measurement of Turkish natural gas distribution utilities for policy recommendations using the DEA method.

Lawrence (2010) estimated the TFP of Australia's Victorian gas distribution businesses (GDB) for operational benchmarking. Lawrence and Kain (2012) used econometric methods for estimation of efficiency and predicted future productivity growth of Victorian gas utilities in Australia by constructing total cost function and operating cost function parameters using data for nine Australian GDBs and two New Zealand GDBs. In general, as the review indicates, efficiency and productivity measures are widely used for incentivizing and setting tariff for natural gas utilities in USA, Europe, New Zealand, Australia, and Canada. In recent times, as the oil & gas sectors are privatized, liberalized, and decontrolled across the globe, frontier based methods are extensively employed to measure and benchmark their performance in the post liberalization period. The results of these studies are used to derive useful information for further fine-tuning the policy.

DEA Methodology

DEA is a non-parametric technique in which linear programing is used to construct the piece wise efficient frontiers (Farrell, 1957). Then the relative efficiency of firms is compared with the firms operating on this efficient frontier. Farrell (1957) provided the frontier concept for measuring efficiency. Charnes, Cooper, and Rhodes (1978) coined the term DEA, provided the mathematical framework, and developed constant return to scale (CSR) model. Banker, Charnes, and Cooper (1984) developed the DEA model based on variable return to scale (VRS) famously referred to as the BCC model. DEA models can be specified as input oriented or output oriented depending upon their objective of minimization of the input vector for a given level of outputs or maximization of output vector for a given level of inputs. The CSR -DEA model or CCR Model for an input orientation is mathematically defined as below.

The following notations (Coelli, Rao, O'Donnell, & Battese, 2005) are adapted for the model. Let N inputs and M outputs be available for I number of firms. For an individual firm *"i"*, the respective inputs and outputs are represented by x_i and q_i as column vectors. For all the *"I"* firms, the inputs and outputs are represented by $X = N \text{ x } I$ matrix and $Q = M \text{ x } I$ matrix.

$$\text{Min}_{\Theta\lambda}\ \Theta$$

Subject to

$$Q\lambda - q_i \geq 0$$

$$\Theta x_i - X\lambda \geq 0$$

$$\lambda \geq 0 \qquad (1)$$

wherein, Θ is a scalar and λ is a I x1 vector of constants. The value of Θ indicates the efficiency of the i^{th} firm and takes any value between 0 to 1, with a value of 1 indicating that the firm lies in an efficient frontier. The linear programme has to be solved for *"I"* times once for each firm in the sample to arrive at the Θ value of each firm. As the model is input oriented, it tries to radially contract the input vector *xi* for the firm *'i'* while still remaining within the feasible set formed by piece-wise linear isoquant. The CRS model assumes that all firms are operating at an optimal scale. But due to various factors like imperfect competition, government regulations, first mover advantage, and so forth, all firms are not operating at optimum scale, and scale efficiency also plays an important role. Following the BCC model, the scale efficiency can be captured through introduction of VRS specifications. The CRS model can be easily modified to account for VRS effect by incorporating convexity constraint in equation (1).

$$\Sigma^{I}_{i=1}\lambda i = 1 \qquad (2)$$

Thus, scale efficiency for firms is obtained by carrying out CRS and VRS DEP models and the resultant efficiency may be decomposed into scale efficiency *(SE)* and pure technical efficiency *(TE)* as follows :

$$TE_{CRS} = TE_{VRS} \times SE \qquad (3)$$

Further, to pinpoint whether the firm is operating under increasing return to scale or non - increasing return to scale (NIRS), by replacing the constraint represented by equation (2) by the following constraint, that is, i.e. sum of λ's is less than or equal to 1 as indicated in equation (4) :

$$\Sigma^{I}_{i=1}\lambda i \leq 1 \qquad (4)$$

If price information regarding inputs and outputs is available, then the DEA models can be extended to measure allocative efficiency of input mix, revenue efficiency of output mix, along with technical efficiency. DEA models can also be formulated by incorporating environmental as well as non-discretionary input and output variables in linear programming equations.

As compared to the other parametric techniques, frontier formed by DEA technique is flexible and can be constructed without the specification of a cost or production function. Given that most distribution utilities are operating under regulated environments and have an obligation to develop infrastructure to meet demand, they can only become more efficient by providing a predefined output level with judicious mix of inputs. Considering these facts, we feel that input orientation DEA model is more appropriate for our study.

(1) Identification of Variables : Multiple input variables and output variables characterize the CGD entities. Regulators can use the benchmarking of these variables for CGD entities across geographical areas for reducing information asymmetry. In this context, DEA based efficiency measure is a suitable approach. For proper application of the DEA technique, it is necessary to provide appropriate input and output variables that best

Table 2. Input and Output Variables

Input	Output
● Capex	● No of Customers
● Opex (O&M)	● Customer density (No of customers/km of pipeline)
● No of Employees	● Types of Customers
● Cost of Employee	● Delivered Volume of Gas (m3)
● Indirect operating costs	● Peak Demand (m3/day)
● Length and type of Pipeline Networks	● Plan Performance Executed (%)
● Cost of capital	● Total installed horsepower of compressor stations
	● Financial turn over

Source: Literature Survey

Table 3. Descriptive Statistics of Input and Output Parameters

Type	Parameter	Mean	Std.Dev	Min.	Max.
Input-1	Length of Steel Pipes (km)	274.13	240.86	7	677
Input-2	Length of PE Pipes(km)	1989.78	2436.33	240	3352
Output-1	Total Volume Delivered (MMSCMD)	0.722	1.095	0.07	3.79
Output-2	No of Domestic Customers	183064.42	261643.91	2099	779333
Output-3	No Of Industrial Customers	414.71	523.79	3	1880

Source: Computed by Author using data from PNGRB (2013)

represent the industry under study. The input variables used by the previous study include the necessary capex for creation of network, opex and manpower for maintaining the network, length, and type of pipeline infrastructure in place to deliver gas, and the cost of capital employed, and so forth. Most of the output variables used by the previous studies comprise of activities pertaining to number, type, and density of customers serviced, volume of gas delivered, peak demand met, and plan performance executed, financial performance, and so forth. From the literature survey on DEA studies carried on natural gas utilities, the Table 2 summarizes some of the widely used input and output variables.

(2) The Data : The dataset for the present study were collected from the annual reports of the Indian CGD utilities and from the PNGRB website. The period under consideration was 2013-2014. Length and type of pipeline networks in a geographical spread forms an important input variable as it represents the underlying infrastructure which links various customers with the network. Since creation of pipeline networks is capital intensive, these parameters also proxy the capex of the CGD utilities. Considering this aspect, for our study, the following input parameters : length of steel pipes and length of MDPE were used as input variables.

The main business objective of CGD utilities is to provide safe, reliable, and environmental friendly fuel to the end users. Thus, the customers as the end users along with their consumption level of end product, that is, PNG, CNG constitute essential output parameters for the CGD sector. Taking into account these facts for our study, the total delivered volume of natural gas in mmsmd and the number of domestic customers and number of industrial customers served by the utilities are used as output parameters. A well balanced dataset of above input and output parameters is available only for 14 of the CGD entities operating in India and for the remaining utilities, it is highly unbalanced. Hence, we chose to pool and compute a single DEA frontier for the period from 2013-14.The summary of descriptive statistics of input and output variables considered for this study are as indicated in the Table 3.

Table 4. Efficiency Score Summary

S. No.	CGD Entity	CRSTE	VRSTE	Scale	
1	Indraprastha Gas Ltd.	0.858	1.000	0.858	DRS
2	Mahanagar Gas Ltd.	1.000	1.000	1.000	-
3	Maharashtra Natural Gas Ltd.	0.790	1.000	0.790	IRS
4	Central U.P. Gas Ltd.	0.402	0.808	0.498	IRS
5	Green Gas Ltd.	0.537	1.000	0.537	IRS
6	Bhagyanagar Gas Ltd.	0.237	0.837	0.283	IRS
7	Tripura Gas Ltd.	0.673	1.000	0.673	IRS
8	Avantika Gas Ltd.	0.335	1.000	0.335	IRS
9	GAIL Gas Ltd.	1.000	1.000	1.000	-
10	Adani Gas Ltd.	1.000	1.000	1.000	-
11	Sabarmati Gas Ltd.	0.411	0.441	0.932	IRS
12	Gujarat Gas Company Ltd.	0.655	0.666	0.984	IRS
13	GSPC Gas	1.000	1.000	1.000	-
14	Assam Gas Company Ltd.	0.391	0.432	0.906	IRS
	Mean	**0.664**	**0.870**	**0.771**	

Table 5. Summary of Peer Count

CGD Utilities	Peer Count
Maharashtra Natural Gas Ltd.	4
Avantika Gas Ltd.	4
Adani Gas Ltd.	3
Gail Gas Ltd.	2
Central U P Gas Ltd.	1
Mahanagar Gas Ltd.	1
Tripura Gas Ltd .	1
GSPC Gas Ltd.	1

The main inference from the above information is that the CGD utilities are heterogeneous in nature, that is, in size and scale as indicated by the mean and standard deviation values of input and output parameters. The high range in the steel pipe network, volume of gas delivered, and number of industrial customers indicate emerging nature of industry environment in the CGD sector.

DEA Results

For the present study, DEAP-2.1 programme developed by the Centre for Efficiency and Productivity Analysis of University of Queensland was used for estimating the efficiency of the DMUs. The progamme is easy to use and can solve both input and output oriented DEA models (Coelli, 1996). Since the main business objective of CGD utilities is to provide affordable, clean green fuel to the customers in the given geographical spread, its efficiency can only be improved by decreasing the amount of inputs. Accordingly, technical efficiency *(TE)* scores under CRS and VRS models are evaluated using input oriented DEA models followed by the estimation of scale efficiency. The results arrived at are depicted in the Table 4.

The *TE* score provides the target level by which the inputs can be proportionally decreased while maintaining the same level of output. The mean CRS *TE* score is 66.4%, and 50% of CGD utilities are operating below this level. Under the VRS model, firms are benchmarked against other firms that are comparable in size ; accordingly, the VRS efficiency scores are generally higher than the CRS and leading scale efficiency measures. The mean VRS score is 87% and five of the CGD have *TE* score less than the mean value. The inferred reason for the inefficiency of the sector is that most of the distribution firms are young and cannot get high penetration and customer switch over, especially in the industrial sector due to high price elasticity of demand and ease of availability of substitution fuel. Furthermore, as most of the CGD utilities are new and are operating in marketing exclusive period ; consequently, there is a lack of competition and these also add to the inefficiency of CGD utilities.

The ratio between the CRS and VRS *TE* score provides the scale efficiency, and the mean scale efficiency in this case is 77.10%. Mahanagar Gas Ltd., Gail Gas Ltd., Adani Gas Ltd., and GSPC Gas are the only CGD utilities which are operating in optimum scale. Majority of the firms (nine in number) are operating in increasing scale of return. These utilities appear to be too small to reach the optimal size of operation. Thus, these firms have proportionally a higher share of network length with respect to their number of customers. Only IGL Ltd. is operating in decreasing scale of operation and the operational inefficiencies associated with its large size and vast network across the National Capital Region (NCR) may be one of the main reasons.

The Table 5 presents the summary of the number of times each CGD in the frontier is a 'peer' or a target for the rest of the utilities. From the results, we can infer that Maharashtra Natural Gas Ltd. and Avantika Gas Ltd. are four times as target for rest of firms and it is good for other firms to study their operating characteristics to emulate them.

Research and Policy Implications

The present study, as per our knowledge, is the first study carried out on measures of efficiency on Indian CGD utilities using the DEA methodology. The resultant efficiency measures indicate that there is vast scope for most CGD utilities to increase efficiency. The main source of inefficiencies in majority of utilities is related to their scale of operation. Smaller and newer utilities are on an average, less efficient due to scale efficiency, and a lot of catchup has to be done by these utilities to reach the efficient production frontier.

As natural gas transmission and distribution is being deregulated in India in a calibrated way, that is, the policy is evolving, these kind of efficiency studies will provide regulators a yardstick for fixing network tariff rate to incentivize companies while protecting the interests of customers. This kind of frontier-based benchmarking method identifies or estimates the efficient production performance frontier from sample best practices. The resultant efficient frontier can be used as a benchmark against which the relative performance of all firms is measured and thus helps the regulator to fine tune bidding parameters. Currently, the regulator PNGRB follows a cost-plus regulation and soon may adopt the widely practised international regulatory framework which emphasizes on more efficient production and cost reduction, wherein the expected efficiency improvement part has to be benchmarked based on empirical results obtained from sophisticated efficiency analysis such as this. Towards that, this work may be considered as an initial step in the Indian context.

Conclusion

Through this study, the technical and scale efficiencies of selected Indian CGD entities using the non-parametric data envelopment analysis (DEA) are calculated. The empirical results indicate that inefficiencies exist in this industry. On an average, the technical efficiency of sample companies is about 66.40%, and the mean scale efficiency is about 77.10%. Another important observation is that eight of the CGD utilities operate in the area of increasing returns to scale and only one in the area of decreasing returns to scale. Apparently, majority of the companies do not operate at optimal levels of production and scale. Diseconomies are an important source of inefficiency. This general result of inefficiency due to sub-optimal utilization of resources is in line with earlier studies carried out in Italy, Turkey, Czech Republic, Australia, USA, and so forth with respect to UCG utilities.

However, in matured markets like USA and Italy, the bulk of companies are operating in decreasing returns to scale. While this study supports the fact that in recently liberalized gas markets like India, Turkey, Czech Republic, and so forth, most of the UCG utilities are subjected to increasing returns to scale, these firms are comparatively new and small in size. On the other hand, old and established utilities are very few and are found to operate very close to the optimal size and thus outperform recent ones with respect to scale efficiency. This fact may suggest that there exists room for improving competition, and increasing scale of operations appears to be a promising strategy to increase technical efficiency. However, considering the fact that establishing CGD infrastructure in new geographical spreads entails huge capital costs, and the majority of the new bid winners cannot increase the spread and number of customers within the short period, this study should be repeated a few years later when these firms increase the penetration rate to arrive at a more meaningful conclusion.

Limitations of the Study and Scope for Future Research

To the best extent of our knowledge, this paper is the first to conduct an efficiency measure in Indian CGD utilities using DEA. However, there are various limitations of the present study. The major limitation is the low number of CGD utilities, and the consequent limit in sample size relaxes the rigorous application of DEA benchmarking methodology. The other main limitation is that we could not consider various environmental factors like the level of urbanization, industrialization, climate, and so forth, which had an effect on the operational and technical efficiencies of these utilities. Further, due to lack of systematic data on cost parameters, the allocative efficiency could not be carried in the present work, but the same is very much essential for benchmarking performance of utilities. The present study has only estimated the variation in efficiencies, but not identified the sources explaining these variations. Further, relative efficiency measures with respect to counterparts in other countries have to be carried out for meaningful international benchmarking exercises. Future research work should be done in this direction, which might provide meaningful managerial and policy implications for adaptation/implementation.

References

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science, 30*(9), 1078-1092. doi: http://dx.doi.org/10.1287/mnsc.30.9.1078

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2* (6), 429-444.

Coelli, T. J. (1996). *A guide to DEAP version 2.1: A data envelopment analysis computer program* (CEPA Working Paper 96/08). NSW, Australia : Center for Efficiency and Productivity Analysis, University of New England.

Coelli, T. J., Rao, D. S. P., O'Donnell, C.J., & Battese, G.E. (2005). *An introduction to efficiency and productivity analysis.* New York, NY : Springer.

Corbeau, A. S. (2010). *Natural gas in India* (International Energy Agency Working Paper). Paris, France : IEA. Retrieved from https://www.iea.org/publications/freepublications/publication/natural_gas_india_2010.pdf

Erbetta, F., & Rappuoli, L. (2003). *Estimating optimal scale and technical efficiency in the Italian gas distribution industry* (HERMES Working Paper6). Vercelli, Italy : University of Eastern Piedmont.

Ertürk, M. (2009). *Efficiency analysis of Turkish natural gas distribution companies by using DEA method* (Master Thesis). Turkey : Middle East Technical University.

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of Royal Statistical Society, Series A, General, 120* (3), 253-281.

Hawdon, D. (2003). Efficiency, performance and regulation of the international gas industry : A bootstrap DEA approach. *Energy Policy, 31* (11), 1167-1178. doi: 10.1016/S0301-4215(02)00218-5

Jamasb, T., Newbery, D., Pollitt, M., & Triebs, T. (2007). *International benchmarking and regulation of European gas transmission utilities.* Final Report prepared for the Council of European Energy Regulators.CEER: Brussels.

Jamasb, T., Pollitt, M., & Triebs, T. (2008). Productivity and efficiency of US gas transmission companies: A European regulatory perspective. *Energy Policy, 36* (9), 3398-3412.

Kim, T. Y., Lee, J. - D., Park, Y. H., & Kim, B. (1999). International comparison of productivity and its determinants in the natural gas industry. *Energy Economics, 21*(3), 273-293. doi: 10.1016/S0140-9883(99)00007-9

Lawrence, D. (2010). *The productivity performance of Envestra's South Australian and Queensland gas distribution systems.* Australia : Economic Insights.

Lawrence, D., & Kain, J. (2012). *Econometric estimates of the Victorian Gas distribution businesses' efficiency and future productivity growth.* Australia : Economic Insights.

Maria, N., Cullmann, A., & Neumann, A. (2010). Overcoming data limitations in nonparametric benchmarking: Applying PCA-DEA to natural gas transmission. *Review of Network Economics, 9* (2), 1-22. DOI: 10.2202/1446-9022.1209

Petroleum and Natural Gas Regulatory Board (PNGRB). (2013). *EOI CGD network 2013.* Retrieved from http://www.pngrb.gov.in/CGD-network.html

Petroleum and Natural Gas Regulatory Board. (2008). G.S.R 197(E) : *PNGRB Determination of network tariff for city or local natural gas distribution networks and compression charge for CNG regulations.* Retrieved from http://www.pngrb.gov.in/OurRegulation/CGD-Network-GSR197.html

Rossi, M. A. (2001). Technical change and efficiency measures: The post-privatization in the gas distribution sector in Argentina. *Energy Economics, 23* (3), 295-304. doi: 10.1016/S0140-9883(00)00067-0

Sadjadi, S. J., Omrani, H., Abdollahzadeh, S., Alinaghian, M., & Mohammadi, H. (2011). A robust super-efficiency data envelopment analysis model for ranking of provincial gas companies in Iran. *Expert Systems with Applications, 38* (9), 10875-10881. doi: 10.1016/j.eswa.2011.02.120

Storto, C. L. (2014). Gas distribution in Italy: A non-parametric analysis of companies operational efficiency. In, X. Zhang, B. Zhang, L. Jiang, & M. Lie, *Advanced materials research* (Vols. 838-841 (01), 1972-1978. doi: 10.4028/www.scientific.net/AMR.838-841.1972

Zorić, J., Hrovatin, N., & Scarsi, G. (2009). Gas distribution benchmarking of utilities from Slovenia, the Netherlands and the UK: An application of data envelopment analysis. *South East European Journal of Economics and Business, 4*(1), 113-124. doi: 10.2478/v10033-009-0008-1