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Cost Efficiency Evaluation and Performance Assessment of Urban Water Supply Utilities In The State of Madhya Pradesh, India

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ABSTRACT

Water is the basic need of the living things in this world and Water Supply Utility fulfils this requirement with quantitatively and qualitatively. In many developed countries water supply services gets the status of profitable Industries and set tariffs according to that. In developing countries like in India Urban water supply Utilities still running by government authorities/undertaking without Public-Private partnership practice in common hence there is need to estimate cost efficiency and assessment of the performance of urban water supply utilities in the state of Madhya Pradesh, India. Stochastic frontier analysis is a parametric approach to estimate the cost efficiency of urban water supply utilities in a very systematic manner with including effect of noise. Significant Models show that Municipality of Bhopal, Morena, Ratlam and Vidisha urban city performed better and scored highest estimated cost efficiencies, while least efficient utility of Hoshangabad Municipal Corporation would decrease their output cost by 35.84% to attain the level of the most efficient utility of the state.

Key Words: Stochastic frontier analysis, cost function, benchmarking, urban water supply

1. Introduction

In urban areas because of rapidly Industrialisation, Urbanisation and unplanned development of houses, building and commercial sectors raises big issues of mismanagement of water supply in a quantity and quality effectively. Because of lack of public - private partnership, existing old infrastructures, and lack of awareness among the people there is a need to assess and evaluate the existing water management utilities of urban cities in the country. Water supply system in urban India suffers from a number of problems. There exists serious mismanagement in water supply system in urban India (Kundu et al., 2006).

Table 1: A status of water supply and sanitation in the state of Madhya Pradesh, India (Source: Central pollution control board, 2009)

Class of City	Population in Year 2008	Water Supply (MLD)	Per Capita water supply (LPCD)	Sewage Generation (MLD)	Sewage Treatment Capacity (MLD)
Class-I city	10795000	1560.91	144.6	1248.72	186.1
Class-II Towns	1745050	163.64	93.77	130.9	9

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Water Supply with quality and quantity and its sustainable management is a hot issue not only in a state but also in a prime agenda of the Country. Sectoral demands for water are growing rapidly in line with urbanization (estimates suggest that by 2025, more than 50 per cent of the country's population will live in cities and towns), population increases, rising incomes and industrial growth, and urban India is fast emerging as centres of demand growth, As a result, per capita water availability has been falling (Planning Commission of Govt. of India, 2002).

The objective of the study is to evaluate the Cost efficiency and the performance assessment of water supply utility of selected urban cities of Madhya Pradesh, India. Sample urban cities have been taken from the classification based on the population as metropolitan city, class-I and class-II city (CPHEEO, 2005).

2. Review of the relevant studies

A very few studies have been done on the benchmarking of water supply utilities by using Stochastic Frontier analysis. In European countries lot of study has been done on benchmarking but for water supply utilities few literatures are available by using stochastic frontier analysis. Table 2.0 shows a clear picture of benchmarking of water supply utilities by using benchmarking methodologies.

Table 2: Summary of findings of the literature review

S. No.	Author(s) Name	Methodology	Function used	Variables
1	Kirkpatrick et al. (2004)	DEA and SFA	Cobb-Douglas cost function, half normal distribution	1. Operating and maintenance costs (US$) – Non capital cost 2. Water distributed per year (m^3) - Output 3. Number of hours of water availability per day – Quality variable 4. Manpower costs per employee (US$) – cost of labor 5. Water resources per capita – control variable 6. Population served per connection – density variable 7. GDP per capita (US$) – (to capture the economic development and quality of governance) 8. Freedom index – control variable (to capture the economic development and quality of governance) 9. No of pipe breaks that occurred in a given network per year 10. Ownership dummy (1=privately owned) – in order to account the effect of ownership on the performance

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2	Nagues et al. (2008)	SFA	Translog Cost function	Out Put variable 1. volume of water delivered, 2. volume of waste water treated Cost variable 1. Labor cost, energy cost and miscellaneous cost Environmental variables: 1. Average duration of water supply services in hours per day 2. Efficiency measure (total volume sold / total volume produced) \ 3. Percentage of metered connection 4. Number of towns served by the utility
3	Filippini et al.(2008)	SFA	Translog Function	Cost variable 1. (operating and capital expenditure) 2. Total Water delivered in m^3 3. Price of labor (avg annual wages / avg no of employee per year) 4. Price of material (material cost / length of the network in km) 5. Price of capital (capital cost / capital stock) or capacity of pumps in litres / second (Capital cost consist of depreciation and interest) 6. No of customers served (Sum of households and non household customers) 7. Size of Area Km^2 8. Water loss(dummy variable) 1 – less water loss, 0 – otherwise 9. Treatment of water (dummy variable) dummy value (1) – chemically treated before distribution dummy value (0) – otherwise

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4	Baranzini et al (2008)	SFA	Translog Cost Function	1. Variable total cost 2. Output (volume of water delivered) 3. labor Price 4. Energy price 5. Material price 6. Capital price Environmental variables 1. Consumer Density (no of customers per meter of network) 2. Load factor (max amount of water distributed per customer per day/mean amount of water supplied per customer per day Dummy Variables 1. pumped water – (1 if utility pumped more than 50% of its water , 0 otherwise) 2. households –(1 if water delivered to household is more than 60%, 0 otherwise) 3. lack or river water –(0 if no water comes from lakes or river or 1 otherwise)
5	Faria et al.(2005)	SFA	Cobb-Douglas production function With truncated normal and exponential	1. Quantity of firms production (volume of water delivered in m^3/year) 2. Capital (length of the piped network) 3. Labor (number of employees) Dummy variable 1. d_1 = Variable nature of the firm (1 for public utility, 0 for private) 2. d_2 … to d_5(are the regional indicators(North, Northeast, Center-West, Southeast, and South).
6	Crain et al. (1978)	SFA	Cobb-Douglas cost function	1. Output of firm (volume of water delivered) 2. Total cost (sum of operating , maintenance and depreciation) 3. Labor price 4. Capital price 5. Ownership dummy variable
7	Bruggink (1982)	SFA	Translog cost function	1. Volume of water delivered – output 2. Labor price, capital price, electricity price – input variables

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8	Byrnes et al. (1986)	DEA/SFA	Production function	Output 1. Volume of water delivered Inputs 1. Ground water, 2. surface water, 3. purchased water, 4. part time labor, 5. full-time labor, 6. pipeline length and 7. Storage capacity.
9	Corton (2003)	SFA	Cost function	Out put 1. Operating cost Input 1. Length of pipe 2. Region of water services(dummy variables) 3. Volume produced by the water company

3. Model Specification and Methodology

A Cobb-Douglas cost frontier using cross-sectional data and assuming a half-normal distribution.

The Cobb-Douglas cost frontier as follows:

$$\ln(C_i/W_i) = \beta_0 + \beta_1 \ln(Q_i) + \beta_2 \ln(R_i/W_i) + (V_i + U_i),$$

where C_i, Q_i, R_i and W_i are cost, output, capital price and labour price, respectively, and V_i and U_i are assumed normal and half-normal distributed, respectively.

Translog Cost Frontier can be defined as:

$$\ln(C) = \beta_0 + \beta_1 \ln(Y) + \beta_2 \ln(P_l) + \beta_3 \ln(P_e) + \tfrac{1}{2}\beta_4 \ln(Y)^2 + \tfrac{1}{2}\beta_5 \ln(P_l)^2 + \tfrac{1}{2}\beta_6 \ln(P_e)^2 + \beta_7 \ln(Y)\ln(P_l) + \beta_8 \ln(Y)\ln(P_e) + \beta_9 \ln(Pl)\ln(P_e) + V_i + U_i,$$

and $\mu = \delta_o + \delta_1 \ln(UFW) + \delta_2 \ln(Area)$

Where Y is water distributed by the utility in MLD, Pl is the prise of labour, P_e is the prise of electricity used by the utility, C is the Total cost of the utility as a output variable. Translog Function also includes two environmental variables Unaccounted for water (UFW) and Area covered by the services of the utility.

To avoid Multicollinearity problem a Cobb-Douglas function is employed (Filippini et al., 2008). The properties of the cost function that it is concave and linearly homogenous in input prices, non-decreasing in input prices and non decreasing in output. Notice that normalization of cost and input prices by one of the input prices is used to impose linear homogeneity in input prices. Hence, the total cost, the price of labour and the price of material are divided by the price of capital. Other properties remain to be verified after the estimation of the translog cost function is conducted. All variables normalized by sample median and are in logarithm to get first order coefficients by using Translog function (Baranzini et al.2008).

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Corton (2003) illustrates the applicability of the framework of benchmarking for developing economies. Author gives a regression model for operating cost by using region variable as a dummy variable to reduce hetroscedacity. According to the Author, in the regulatory context, the cost frontier is of primary concern.

Table 3: Descriptive analysis of the input and output data in Stochastic cost function

Variable description	Variable notation	Mean	Standard deviation	Minimum	Maximum
Total volume of delivered water (mld) per year Y	Y	51.47222222	83.44912	4.7	270
total cost (Rs in lakhs)	C	387.7111111	720.459	15.4	2773
Price of labour (avg annual wages Rs in lakhs)	P_l	108.0666667	180.9711	5	608
Prize of Electricity (Rs in lakhs)	P_e	180.85	413.2616	0.5	1500
Operating cost = (Total cost - Depreciation - interest - debit) (Rs In lakhs)	P_o	840.0444444	1982.035	4	8244
Density of customers (population in '000/ Area of service).	Dens	5.498568	3.625509	1.331689	15.95197
Unaccounted for water (loss) (Mld)	UFW	8.585294	21.07746	0.02	81

Table 4: SFA Model description on stochastic cost function applied on water supply utility of urban cities of Madhya Pradesh, India

Model No.	**Output variables**	**Input variables**	**functional form**	**Results**
Model 1	1. C	1. Y 2. Pl 3. Pe	Cobb - Douglas Cost function	Estimated efficiencies not significant
Model 2	1. C	1. Y 2. Pl 3. Pe	Translog cost function truncated normal Error component Model	ML = 20.05, η = 88.4% LR = 8.024 with number of restriction 2> Critical value (5.138) (H0, rejected) γ = 0.9999
Model 3	1. C	1. Y 2. Pl 3. Pe	Translog cost function truncated half normal Error component Model	ML = 19.216, η = 87.83% LR = 6.351 with no of restriction 1> Critical value (2.706) (H0, rejected)

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Model 4	1. C	1. Y 2. Pl 3. Pe Exogenous variables: 1.UFW(dummy) 2. Area of service (Env. Variable)	Translog cost function truncated normal TE Model	ML = 20.425, η = 88.89% LR = 8.763 with number of restriction 4> Critical value (8.761) (H0, rejected)

3.1 Interpretation of Results and discussions of Significant Model 2 and Model 4:

3.1.1 Test of Hypothesis

By adopting Battese and Cora parameterisation, the hypothesis should be involve parameter γ. Coelli(1995) suggested that the one sided generalised likelihood ratio test should be performed to check the hypothesis validity, when Maximum Likelihood estimation is involved , because this test has the correct size. All relevant hypotheses were tested using the generalized likelihood-ratio statistic, $\gamma = -2\{\ln L(H_0) - \ln L(H_1)\}$, where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null (H_0) and the alternative (H_1) hypothesis. The above test-statistic has approximately a χ^2 distribution, except the case where the null hypothesis involves also $\gamma = 0$. Then, the asymptotic distribution of λ is a mixed χ^2 (Coelli 1995) and the appropriate critical values are obtained from Kodde and Palm (1986, Table I). It should be noted that any likelihood ratio test statistic involving a 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 the parameter space. In this case the likelihood ratio statistic has been shown to have a mixed chi-square distribution.

3.1.2 Null Hypothesis

(H_{o}): $\mu=0$ versus alternate Hypothesis (H_{1}): $\mu_1>0$,
If $\mu=0$, the half normal Model is an adequate representation of the data.
If H_o is true, this test statistic is usually assumed to be asymptotically distributed as a chi-square random variable with degree of freedom equal to the number of restrictions involved.

In Model 2 and Model 4, H_o is reject in favour of H_1 because LR (one sided genralised likelihood ratio test is greater than critical value as obtained from Table-1 of Kodde and palm(1986). Hence Normal Model is adequate representation of data for water supply utility of urban cities in the state of Madhya Pradesh, India.

Table 5: Estimated efficiency of the water supply utility of urban cities in the state of Madhya Pradesh, India

Utility	Urban city of	Year	Estimated	Estimated

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No.	**the utility**		**efficiency in (%) in Model 2**	**efficiency in (%) in Model 4**
1	Bhopal	1	94.6	97.08
2	Indore	1	94.1	96.1
3	Bhind M	1	92.2	95.2
4	Guna M	1	77.9	75.7
5	Gwalior M. Corp.	1	80.3	85.4
6	Jabalpur M. Corp.	1	97.1	98.0
7	Morena M	1	99.9	100
8	Ratlam M. Corp.	1	99.8	100
9	Rewa M. Corp.	1	78.2	75.1
10	Satna M. Corp.	1	96.2	98.0
11	Shivpuri M	1	87.5	89.6
12	Hoshangabad M	1	64.1	62.8
13	Khargone M	1	90.4	93.4
14	Mandsaur M	1	85.9	84.7
15	Neemuch M	1	97.2	96.1
16	Sehore M	1	93.0	89.5
17	Shahdol M	1	87.6	92.6
18	Vidisha M	1	94.9	100
	Mean efficiency		**88.4%**	**88.89%**

Table 6: Results of elasticity of coefficients of Model -2

Coefficient	**Notation**	**Elasticity of coefficients**	**Standard error**	**T-ratio**
Constant	β0	1.49	0.549	2.73
Y	β_1	-0.35	0.264	-1.33
P_l	β_2	0.55	0.787	0.705
P_e	β_3	0.85	0.450	1.89
Y^2*0.5	β_4	0.0095	0.0687	0.138
P_l^2*0.5	β_5	-0.12	0.131	-0.922
P_e^2*0.5	β_6	0.13	0.113	1.18
Y*P_l	β_7	-0.17	0.281	-0.588
Y*P_e	β8	-0.084	0.0722	-1.16
P_l*P_e	β_9	0.017	0.137	0.122
sigma-squared	σ^2	0.026	0.0099	2.62
gamma	γ	0.99999	0.00414	241.71

Table 7: Results of elasticity of coefficients of Model -4

Coefficient	Notation	Elasticity of coefficients	Standard error	T-ratio

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Constant	$\beta 0$	1.51	0.837	0.180
Y	β_1	-0.360	0.182	-1.97
P_l	β_2	0.542	0.854	0.634
P_e	β_3	0.848	1.18	0.721
Y^2*0.5	β_4	0.0161	0.140	0.115
P_l^2*0.5	β_5	-0.0897	0.633	-0.142
P_e^2*0.5	β_6	0.133	0.146	0.909
Y*P_l	β_7	-0.140	0.318	-0.441
Y*P_e	$\beta 8$	-0.0856E	0.0652	-1.31
P_l*P_e	β_9	-0.0147	0.705	-0.0208
delta 0	δ_0	-0.147	0.454	-0.323
dummy UFW	δ_1	0.276	0.377	0.731
Area of Service (Z_1)	δ_2	-0.0000362	0.00490	-0.00740
sigma-squared	σ^2	0.0277	0.0283	0.977
gamma	γ	1.00	0.130	7.72

Table 8: Requirement of % cost savings in output cost of Water supply (MLD)

Water Supply Utility	**Requirement of cost saving % in output cost of water supply Model 2**	**Requirement of cost saving % in output cost of water supply Model 4**
Bhopal	5.305305	2.92
Indore	5.805806	3.9
Bhind M	7.707708	4.8
Guna M	22.02202	24.3
Gwalior	19.61962	14.6
Jabalpur M. Corp.	2.802803	2
Morena M	0	0
Ratlam M. Corp.	0.1001	0
Rewa M. Corp.	21.72172	24.9
Satna M. Corp.	3.703704	2
Shivpuri M	12.41241	10.4
Hoshangabad M	35.83584	37.2
Khargone M	9.50951	6.6
Mandsaur M	14.01401	15.3
Neemuch M	2.702703	3.9
Sehore M	6.906907	10.5
Shahdol M	12.31231	7.4
Vidisha M	5.005005	0

4. Conclusion

The present study has analysed the cost efficiency of water supply utility of selected urban cities in the state of Madhya Pradesh, India. This is first time to study about the efficiencies of urban water utilities in the state of Madhya Pradesh by using stochastic cost frontier benchmarking technique. Significant

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Models show that Municipality of Bhopal, Morena, Ratlam and Vidisha urban city performed better and scored highest estimated cost efficiencies while evaluation is based on SFA cost function using data given by CPHEEO, 2005. The Mean efficiency in Model 2 is 88.4 % and in Model 4 is 88.89% which suggest that Water supply utilities could minimize their output cost by 11.6% (Model 2) and 11.11% (Model 4) without minimizing their inputs (see Barrosa et al. 2007) which in this case Prize of labour and prize of energy. The utilities having mean efficiency 88.4% (Model 2) to attain the most efficient utility of the state, would experience a cost savings of water supply by 11.51% {1 - 88.4/99.9)*100}% , (see Mbanasor et al., 2008). The utilities having mean efficiency 88.89% (Model 4) to attain the most efficient utility of the state, would experience a cost savings of water supply by 11.11% {1 - 88.89/100)*100}% .

Least efficient utility of Hoshangabad Municipal Corporation would decrease their output cost by {(1 – 64.1/99.9)*100}% = 35.84% to attain the level of most efficient utility of the state.

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