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Measuring the performance of water service providers in urban India: implications for managing water utilities

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Abstract

This study assesses the efficiency of the urban water supply system in 27 selected Indian cities. It applies data envelopment analysis (DEA) as an analytical tool to measure technical efficiency. Cities are categorized into different groups according to the management structure of their water utilities. The results show that within groups, the utilities that are managed by 'municipal corporations (MCs) and parastatals', with a certain amount of functional autonomy, perform better in comparison to the group 'MCs and government' and thus, strengthen the hypothesis that functional autonomy in management leads to better performance of the water utilities. Moreover, the results also have implications for urban domestic water pricing. We find that most water utilities are operating under decreasing returns to scale (DRS), implying that water should be priced at a marginal cost of supply.

Keywords: Data envelopment analysis (DEA); Efficiency; India; Municipal corporations; Parastatals; Urban water

1. Introduction

Provision of an adequate water supply to a growing urban population is a daunting task worldwide (Nallathiga, 2006). This assumes greater significance in the context of India owing to its implications for economic growth, productivity and poverty reduction (Mathur & Thakur, 2003). It is estimated that by 2025, 50% of Indians will reside in urban areas (India Assessment, 2002). Given this growth of the urban population coupled with increasing usage of water due to increasing incomes and declining water quality because of groundwater contamination and surface water pollution, water problems might be aggravated in almost all urban conurbations in India. Recognizing the importance of the water sector, the emphasis should be on improving performance through reforming the management institutions,

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policies and planning systems (World Bank, 2002). Therefore, it is reasonable to look at the existing structure and functions of the urban water supply system and to examine the level of performance of water utilities in India.

The water supply system in urban India suffers from multiple problems, including mismanagement (Singhal & Johri, 2002; Kundu & Thakur, 2006). The predominant problems confronting the urban water supply system are intermittent and irregular water provision, inefficient and inequitable allocation of resources, low tariffs, a high level of fiscal dependence, poor management of consumer concerns and high coping costs (Ministry of Urban Development and Poverty Alleviation, 2004). It is riddled with the problems of operation and maintenance (O&M), low water pressure, ill-designed transmission and distribution systems, poor water quality, unequal distribution within the cities and high unaccounted-for water (UFW) (Pangare *et al*., 2004; TERI, 2010) resulting in high financial and health costs (McKenzi & Ray, 2009). Considering the above facts necessitates examining the strengths and weaknesses of urban local bodies providing water by using performance measurement approaches to direct them to perform efficiently.

The need for performance measurement of cities is well documented (Osborne & Gaebler, 1993; Ammons, 1996; Wood, 1998). Performance measurement can be defined as a technique to determine how effectively and efficiently an urban local body delivers the required service. It examines both the quantitative and qualitative aspects of an agency's functioning. Moreover it establishes a connection between policy options and their outcomes. The use of this technique is not new in water utilities. Many countries have adopted this technique to improve the performance of their utilities. The inherent characteristic of serving as an effective incentive mechanism makes the performance measurement technique an appealing instrument. Usually two different categories of performance benchmarking techniques are employed by scholars. One is the average analysis or simple ratio measures[1], sometimes called as the partial productivity index, and the other one, which takes into account all the inputs used and outputs produced by the utilities, is called the total factor productivity measures. The total factor productivity measures are based on either regression analysis (RA) or data envelopment analysis (DEA) techniques.

The present study uses the output-oriented DEA approach to estimate the relative efficiency of 27 cities in the provision of water services in urban India for the year 2004/05. Given the existing distortions in the availability cost data, it is reasonable to employ DEA, which is less reliant on information. Further, use of the technique of regression requires prior knowledge of the functional form, whereas DEA does not require these kinds of assumptions regarding the specifications of production technology.

The rest of the paper is organized as follows. Section 2 describes the existing urban water supply situation and the inherent problems associated with it. Section 3 reviews some select literature analysing the efficiency of the water sector. The focus here is to review literature analysing the effect of ownership on performance on a comparative basis. Section 4 elaborates the methodology adopted and the estimation technique followed. Section 5 describes the data. Section 6 spells out the results derived from the study and the final section gives a conclusion.

[1] Ratio estimates are frequently used in partial productivity measures where the ratio of output to input gives a partial idea of the efficiency of a sector. For instance lpcd (litres per capita per day) is a ratio of quantity of water to population number, describing the per capita availability of water, irrespective of the use of resources.

2. Some facts about urban water supply in India

The responsibility for supplying water in urban India is vested in sub-national governments. While the central government formulates overall policies for the development of the water sector in urban areas, state governments lay down detailed policies and set up institutions for the proper development and management of water systems in these areas.

The institutional setting for providing water in urban areas varies from state to state. State level public health engineering departments (PHEDs), specialized state-wide water supply and sewerage boards (WSSBs), specialized city-level WSSBs, municipal corporations (MCs) and urban local bodies, are the leading providers of water in urban India. Apart from these, some other bodies such as various ministries and departments, financial institutions, external support agencies, non-governmental organizations (NGOs) and private sectors also play direct and indirect roles in water supply.

A brief description is given here of the existing situation for some leading indicators of the water supply system on a comparative basis for some select cities[2]. Data are collected for a cross section of 27 Indian cities for different variables. The principal data source for our study is the different volumes of city development plans (CDPs) available online on the website of the Ministry of Urban Development, Government of India. These CDPs give information about the various dimensions of water supply system in different urban units of India. A comparison is made for the variables such as litres per capita per day (lpcd) of water supply, water connections per thousand population, per capita revenue expenditures, hours of water supply, percentage of population served, and so on.

2.1. Litres per capita per day of water supply

This gives an idea of the quantum of water availability. It is calculated on the basis of present population of the city. The National Drinking Water Mission (NDWM) in the late 1980s fixed 140 lpcd as the norm. Half the cities are far below from the prescribed norm. The average lpcd of water supply is lowest in Guwahati (41.23 lpcd) and highest in Chandigarh (about 8 times that of Guwahati)[3]. Although the average for our sample is 156 lpcd, there is wide variation across cities (Figure 1). The existing variations can be attributed both to the quantum of water available in a city and total population of the city.

2.2. Water connections

2.2.1. Water connections per 1,000 population. A comparative assessment of the data for 23 cities for water connections shows that the connection per 1,000 people is highest in Vadodara, that is 185.4, and lowest in Greater Mumbai, that is 29.35. The low figures for Mumbai are probably due two reasons. One, Mumbai is one of the most densely populated metropolises of India and it houses a high proportion of a slum population. Second, Mumbai has mostly multi-storied apartments; each apartment has one

[2] The selection of cities from the 63 cities covered by the JN National Urban Renewal Mission was constrained by availability of data.

[3] Note here that the lpcd figures quoted in CDPs do not consider water sourced from individuals. In many cities such as Guwahati and Mysore, individuals and municipalities use bore wells to augment water supply Therefore, the lpcd figures should be considered as ballpark figures to give an idea of the availability of water in different cities.

Fig. 1. Litres per capita per day (lpcd) water supply.

metered connection. Within an apartment block, the billed amount is shared between all the flats. Again, there are significant variations across cities. It is doubtful whether the water connection figures ensure that water is available to the people. It might be possible that connections are there but water is not physically available (Figure 2).

2.3. Annual per capita revenue expenditure

The revenue expenditure comprises expenditure on O&M of the utilities, establishment costs, debt servicing and so on. Annual per capita revenue expenditure is calculated by dividing the total revenue expenditure by the population number served by the utilities. An analysis of 27 cities shows that the annual per capita revenue expenditure is highest in the Itanagar, that is Rs 1,219.18, followed by Hyderabad (Rs 556.58) and Chandigarh (Rs 511.47) and lowest in Surat (Rs 11.60). The mean annual per capita revenue expenditure is Rs 185[4] (Figure 3).

2.4. Water availability (hours/day)

2.4.1. Mean hours of water supply. The ‘mean hours of water supply’ indicates the average hours of water supply from the public system in a city. Available data for 23 urban localities show that Ludhiana fares well and the public water system in Ludhiana supplies water for about 12 h in a day followed by Chandigarh which supplies 11 h of water in a day. On the other hand, the water supply in cities like Rajkot, Vishakapatnam, Indore and Vadodara is very poor, ranging from 30 to 45 min per day. This appears rather contradictory when the lpcd figures for Rajkot and Vishkapatnam are compared and contrasted with the mean hours of water supply figures. One possible reason for such an inconsistency may

[4] Although annual revenue expenditure does not completely reflect the status of the water supply utilities in cities, however, given the data constraints, it does at its minimum, give a rough idea of the financial status of the water utilities in India.

Fig. 2. Water connections per 1,000 population.

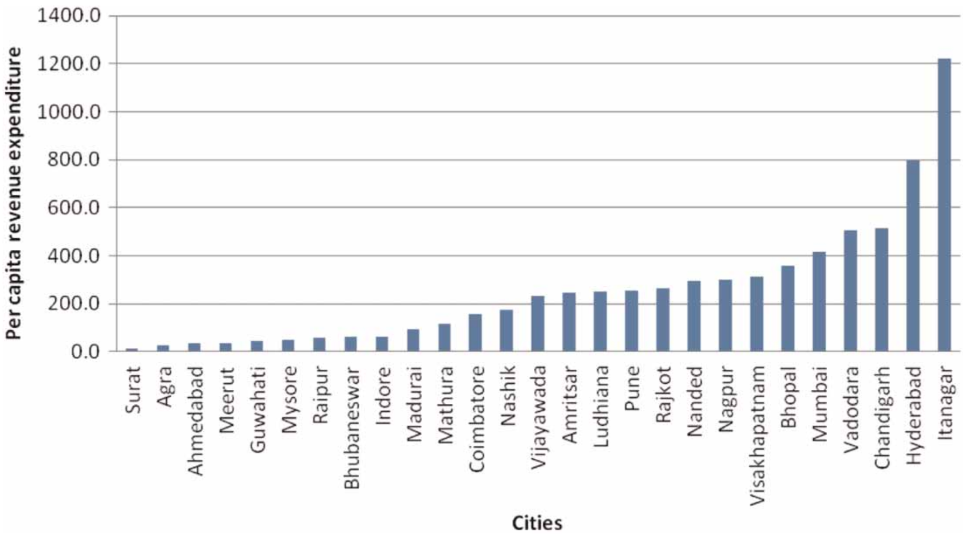

Fig. 3. Per capita annual revenue expenditure.

be linked to overstated lpcd figures. The average number of hours of water supply among all cities is 3.7 h. If we compare these figures with those from some cities of Asian countries, we find that almost all Indian cities analysed here perform very badly. For example, cities like Singapore, Hong Kong, Seoul and Kuala Lumpur have a full-time water supply (Figure 4).

2.4.2. Percentage of population served. This measure indicates the proportion of the population in the service area who receive water from the public water system. The ratio between the total population of

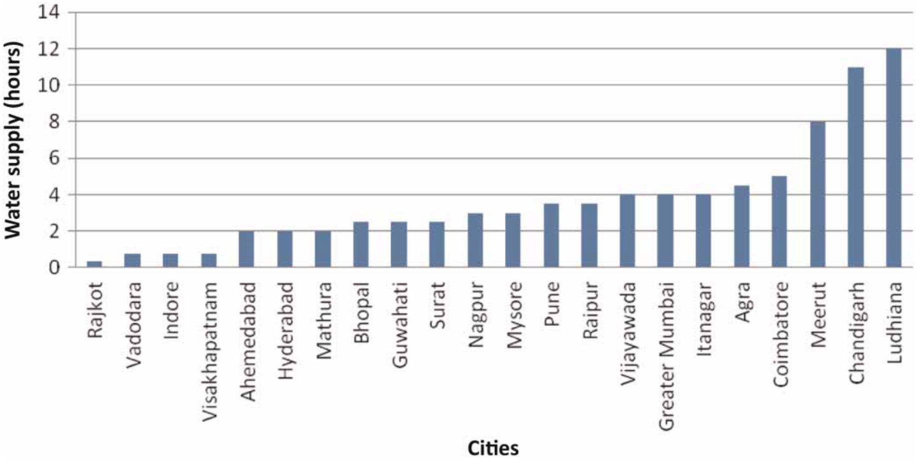

Fig. 4. Mean hours of water supplied.

the city and population served by the public water system gives us the indicator of the 'percentage of population served'.

A calculation for 27 cities reveals that almost all people are served by the water supply system in Chandigarh, Madurai, Rajkot and Greater Mumbai, in contrast to cities like Vijayawada, Visakhakpatnam and Guwahati, where the public water supply system only manages to serve about 30% of the total population of the city. It must be cautioned here that, while examining the appropriateness of this indicator as a measure of the effectiveness of the water supply system, one must keep in mind that the dramatic growth in population in almost all the urban localities distorts the ratio significantly (Figure 5).

The above description of selected cities illustrates the physical dimensions of the water supply situation in urban India. Apart from these concerns, there are considerable problems of governance in the water

Fig. 5. Percentage of population served.

supply system in urban localities in India in terms of lack of transparency and accountability in their function, resulting in a poor level of performance (WSP, 2006). The unhealthy water supply problem in urban India is because of poor cost recovery, tariffs not reflective of cost of service, inappropriately targeted and ill-defined subsidies and inadequate investments (World Bank, 1999). A brief account is given here of some dimensions of the existing problems in the provision of water in urban India.

2.5. Unviable pricing policy

Poor pricing policy fails to provide the required incentives to improve the system both technically as well as institutionally (Mathur & Thakur, 2003). Present prices do not cover even half of the O&M costs of urban water and the continuation of the subsidy does not have any rationale as it is not benefiting the targeted poor (Reddy & Mahendra Dev, 2006). Rather, the subsidy encourages inefficient water use and threatens the sustainable supply of water (TERI, 1995). Thus, the revenue generated from user charges falls short of the expenditure made for supply of water, as a consequence of which assets deteriorate putting a question mark on the financial sustainability of the services. Further, the financial sustainability is hindered by the existence of a low level financial management and accounting system, high capital and O&M costs, overstaffing and a very high level of non-revenue water, the existence of high levels of subsidies and a single-entry cash-based accounting system that does not have sufficient information to make the system transparent.

2.6. Managerial inefficiency

It has been argued that the deficiency in the availability of water in urban conglomerations is due to the existence of weak managerial capacity (Kundu & Thakur, 2006). The spectrum of skills and expertise that are required to undertake the managerial challenges do not seem to be present in many of the urban local bodies in India (NIUA, 1998). The management structures are not unified, reflecting a lack of coherence in the decision making process.

2.7. Poor institutional set-up

The institutional set up of the water and sanitation sector of urban India is characterized by the abstence of an effective regulator and a lack of controls and coordination between the concerned agencies. The existence of multiple institutions and lack of coordination among them results in ambiguous and unclear responsibilities (Singhal & Johri, 2002).

Simply listing the problems of urban water supply in India is not enough and the need of the hour is to find an appropriate solution which is Pareto[5] improving. To find such a solution within the existing resource constraint, it becomes necessary first to measure the extent of inefficiency, that is, how much service quality can be improved by making better use of the existing inputs. It is also a hard fact that all utilities are not equally inefficient; some may be more inefficient in comparison to their peers. We also know that in India, different bodies, such as PHED of state governments, MCs and

[5] A pareto improving situation is defined as a situation where resources should be allocated in such a way as to make someone better off without sacrificing the well being of others.

parastatals[6] manage the urban water supply. Therefore, the present study first tries to measure the extent of technical inefficiency of urban water supply bodies of selected cities and then attempts to relate the performance of these bodies to their management structure.

3. Analytical review of recent literature

The debate on ownership and its linkage with efficiency in the water sector originated with the seminal paper by Crain & Zardkoohi (1978). They assessed the relative efficiency of public versus private water utilities in the United States with the use of a log linear cost function derived from a generalized Cobb–Douglas production function. To estimate the cost function, labour and capital were taken as two input variables and a dummy was incorporated to examine the effects of ownership on the efficiency of the sector. The paper concludes that publicly owned utilities had higher costs and lower labour output elasticity in comparison to their private counterparts. Although this paper initiated the debate about measuring the comparative efficiency of public versus private ownership, it is not without criticism. The assumption of homogeneous output appears to be inappropriate and non-inclusion of opportunity cost of capital sounds illogical in a sector like water where capital costs constitute a significant portion of the total cost.

Similarly, Bruggink (1982) carried out an analysis measuring the relative efficiency of public versus private ownership in water utilities and concludes that private operators are relatively better than others. However, based on a variation of the Chow test, he finds that ownership does not have any significant effect on the structure of the cost or underlying production functions.

Feigenbaum & Teeples (1983) criticize Crain & Zardkoohi (1978) and Bruggink (1982) on methodological grounds. They approached the problem from a different perspective with the use of a hedonic cost function technique. They conclude that there is a little difference in the performance levels between the private operators and public operators. Non-inclusion of capital costs in the Feigenbaum & Teeples (1983) model was also criticized (Coelli & Walding, 2005). A further development in this debate was added by Teeples & Glyer (1987). Using the water utilities data of California, the authors analysed the earlier studies by Crain & Zardkoohi (1978), Bruggink (1982) and Feigenbaum & Teeples (1983) on a comparative basis. They reached the view that the differing results in these earlier studies were due to the existing model restrictions implicit in all the studies.

Byrnes *et al*. (1986) attempted to assess the relative efficiency of private versus public ownership in water utilities using the linear programming technique of DEA. They specified the production model with a single output variable, the volume of water delivered and seven input variables: ground water, surface water, purchased water, part time labour, full time labour, length of pipe line and storage capacity. The authors found that there is not much difference in the technical efficiency scores of private versus public firms.

Lambert & Dichev (1993) also carried out a comparative assessment of the performance of private versus public water utilities. The DEA technique was used to calculate the efficiency scores for 238 public and 32 private firms. The data were taken from American Water Works Association (AWWA). The study concluded that the major source of inefficiency is technical inefficiency. There is little difference between the performance of private and public firms.

Estache & Kouassi (2002) attempted to work out the determinants of efficiency levels achieved by 21 African water utilities. The results show that corruption is negatively linked to efficiency while

[6] Parastatal bodies are part of the government with some degree of functional autonomy, e.g., the Delhi Jal Board (DJB).

governance is positively associated with efficiency. Analysing the effects of privatization, they found that privatization does have an impact on the performance of the water utilities. This is in contrast to the study carried out by Estache & Rossi (2002) for Asia, where they concluded that there is no significant difference between private and public operators.

Kirkpatrick *et al*. (2006) also address the issue of ownership and its effect on the performance of the sector. This study examines the effects of privatization on the performance of the sector using data from African water utilities. Both the stochastic frontier analysis (SFA) and DEA techniques are used for the analysis. The result shows that there is not much difference between the performance of the privately owned utilities and publicly owned utilities.

Despite the existing inefficiency concerns in the urban water supply situation in India, to our surprise there is a dearth of literature examining this aspect using techniques like RA and DEA, except two studies authored by one of us (Kumar, 2010; Kumar & Managi, 2010). Earlier attempts to examine the issues of (in)efficiency in the supply of urban water were confined mostly to using some partial productivity measurement methods (Singhal & Johri, 2002; WSP, 2006).

Singhal & Johri (2002) in their paper point out the existing deficiencies in the water supply management system in urban India and suggest the use of performance management indicators to improve the deteriorating water management system. WSP (2006) develops some performance indicators using ratio methods to measure the efficiency of water supply systems in selected urban localities. Performance data were collected for 13 utilities covering 23 cities and towns across India. The indicators chosen were investment, financial, billing and collection, quality, costs and staffing, network, metering, UFW, production/consumption, coverage and so on. A detailed analysis was carried out within the sample to elicit the performance levels among cities. Further, the overall sample average was also compared with international benchmarks. WSP (2006), in a similar fashion to the other study (e.g. Singhal & Johri (2002), applies ratio methods to evaluate the cities in terms of their ability to supply water. From a methodological point of view it can be argued that ratio methods are incapable of reflecting the true performance of the utilities.

Studies by Kumar (2010) and Kumar & Managi (2010) use a similar set of data gathered from an ADB survey of Indian water utilities in 2005. One of the studies (Kumar, 2010) measures the performance of 20 urban utilities by making use of a directional distance function as an analytical tool. It suggests that at the mean level, Indian water utilities have the potential to increase water delivery levels and reduce UFW by 20%. About half the potential can be realized by altering the scale of operation. The regression results suggest that the length of distribution network and percentage of water connection metered are major determinants of the performance of water utilities.

Kumar & Managi (2010) assess the impact of service quality on performance. The number of hours of water supply and the pass rate of chlorine are considered indicators of quality in water service delivery. DEA is applied to measure the performance of utilities under varying returns to scale. The results suggest that the performance of the utilities changes significantly when conventional quantity-based measures are compared with quality-adjusted measures. The study finds that without quality considerations, an average Indian urban water utility has the potential to increase accounted-for water by 47%, of which 22% can be attributed to operating at optimal scales and the rest could be due to emphasis on management considerations. But results with the inclusion of quality parameters suggest that the potential to increase the accounted-for water is about 38 and 34% could be gained by operating at the optimal scale.

From the review of above cited studies, there is no clear-cut evidence as to which type of ownership is superior to another. The results are mixed in nature. In certain cases, it is observed that differences in results can be attributed to the different methods used for analysis. Therefore necessary caution must be taken while deciding on a particular method for a particular situation. The present study extends the literature on efficiency and ownership of water utilities by measuring the technical efficiency of Indian water utilities. Although the Indian urban water supply system is not fully privatized, the utilities face differing levels of autonomy in management.

4. Methodology and estimation

Techniques such as ordinary least square (OLS), SFA and DEA were used in analysing the efficiency of the water industry in various countries. Though the OLS technique is easy to use and simple to interpret, it suffers from the problem of specifying the functional form for the production technology and is unable to provide information on frontier performance. SFA, although able to solve the latter problem by specifying a composed error term, splitting the error into two different parts as a data noise term and error due to the inefficiency, also suffers from the problem of specifying the functional form and requires specification of the distribution patterns of the error terms that it includes.

The study uses the output-oriented DEA technique which does not require specification of either the functional form and/or the distributional form of the error term, although the major disadvantage of this approach is that it does not accommodate the effects of data noise, which OLS and SFA do. DEA basically erects a production frontier consisting of most relatively technically efficient municipalities in the sample. This process generates technical efficiency measures for each unit in the sample by comparing observed values (the particular data point) to optimal values of outputs and inputs. A score of unity represents the best performing unit in the sample and a score of more than that implies that the unit or the service is not performing as well as its efficient peers. A rather interesting implication of the DEA score is that it also indicates how much more output could have been produced, if the given service could somehow emulate the production process of an efficient one, that is, one which is operating at the frontier of the production technology. The basic model of DEA can be briefly stated as follows.

Output-oriented measures of technical efficiency tell us how much more a water utility can produce from a given amount of resources. This can be illustrated by Figure 6. Suppose there are three water utilities producing two outputs, y_1 and y_2 (lpcd and population served) and each uses one input (revenue expenditure). Further assume that first two utilities are benchmark utilities; they are on the boundary of best practice for the technology. Utility 3 employs the same quantities of inputs as used by utilities 1 and 2, but produces less of both of the outputs, it is in the interior of the output set and obviously not as efficient (productive) as utilities 1 and 2. If we measure the deviation of utility 3 from the best practice frontier in a radial way, its relative technical efficiency is given by ob/oa, which can also be thought of as the ratio of maximum potential output (at b) to observed (actual) output (at a). We measure technical efficiency of water utilities under constant and varying returns to scale. The formal technical details of the methodology are provided in the Appendix (available online at http://www.iwaponline.com/wp/014/109.pdf).

5. Description of data

The present study has taken 27 cities into consideration for the analysis. Although to date more than 60 CDPs are available, the unavailability of the required information restricted us to analysing the

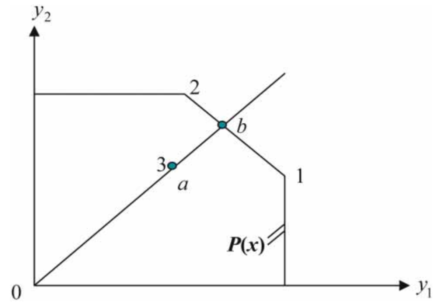

Fig. 6. Output-oriented measures of technical efficiency for water utilities.

efficiency only for 27 cities with fixed number of variables at a single point in time. The cities which are analysed in the present study are: Agra, Ahmedabad, Amritsar, Bhopal, Bhubaneswar, Chandigarh, Coimbatore, Guwahati, Hyderabad, Indore, Itanagar, Ludhiana, Mathura, Meerut, Mumbai, Madurai, Mysore, Nagpur, Nanded, Nashik, Pune, Raipur, Rajkot, Surat, Vadodara, Vijayawada and Visakhapatnam. The selection of inputs and outputs for the estimation of technical efficiency is based on the availability of data as well on the knowledge gained from the literature survey. The variables chosen for the present analysis are as follows: revenue expenditure (rupees/year), water production capacity and water served[7]. The first two variables are treated as inputs and total water served is used as output. Table 1 provides descriptive statistics for the variables used in measuring performance and the cause of variation in performance.

Some clarification is needed with regard to the data used in the model. The revenue expenditure generally constitutes recurring expenditure on establishments, repairs and maintenance, debt servicing, and so on. It is also imperative to mention that some other variables could have better served as input variable indicators, but the unavailability of data prevents us from including these relevant variables. On similar grounds, our analysis is limited in focusing only on a single (total water served) output variable. Therefore, we analyse the model using the data for single output, total water served by a water utility as a function of revenue expenditure and water production capacity.

A few points on the existing data inaccuracies and inconsistencies merit mention here. The available data are not standardized across CDPs. For example, somewhere the units of water available are mentioned in MLD (million litres per day), whereas in other CDPs it is in MGD (million gallons per day) units. Further, a high degree of aggregation also handicapped us by restricting our analysis to an aggregated level. For example, for cities like Raipur and Coimbatore, the variable of revenue expenditure and all its subcomponents are available but this is not the case for other cities like Ahmedabad and Madurai.

6. Results

Using the above data set, output-oriented technical efficiency scorings are generated for the above-mentioned cities and are presented in Table 2. Recall that we are using an output-oriented measure of technical efficiency, therefore efficiency scores greater than one imply that the utility has the potential to increase its output for the given level of inputs. The efficiency estimates reveal that two cities, namely

[7] Water served is defined as lpcd multiplied by the population of the city.

Table 1. Descriptive statistics.

Variable	Unit	Mean	Standard deviation	Max	Min
Revenue expenditure	Million rupees	443.55	1,037.10	5,160.09	1.84
Water production capacity	Million litres	395.04	623.00	3,100.00	1.80
lpcd of water supply	Litres	152.60	72.30	332.00	41.23
Population served	Percentage	74.15	23.70	100.00	27.00
Total water supplied	Million litres	345.45	599.80	3,158.53	6.40
Per capita revenue expenditure	Rupees	179.34	183.82	676.65	11.60
Storage capacity	Million litres	153.61	205.77	782.00	3.00

Agra and Surat, are operating at the frontier. These cities are also operating at the optimal scale of operation. In both of these cities the per capita revenue expenditure is the lowest (in Surat about Rs 12 and in Agra about Rs 20) and the lpcd is higher than the average. On the other hand, Mathura, Bhopal, Visakhapatnam, Nashik and Itanagar are the worst-performing cities, and have the potential to increase the quantity of water supplied by three to eight times. For example, Itanagar has the highest per capita revenue expenditure and lpcd is just 137 litres. Similarly, Bhopal spent around the national average of per capita revenue expenditure but delivers only 88 litres of water on an lpcd basis. The other cities have the potential to increase the desired output by up to three times. The regression results in Table 4 also confirm that there is a direct relationship between per capita revenue expenditure and technical inefficiency and an indirect association between technical inefficiency and lpcd.

The overall average values for scale inefficiencies reveal that the utilities are not utilizing their resources optimally. We find that Itanagar, Guwahati, Pune and Ahmedabad are the most scale inefficient water utilities. These water utilities can improve their performance by changing the level of their operation. If we consider Mathura as an outlier, the overall average figures still do not appear to improve significantly.

Recall that technical efficiency is decomposed into scale efficiency and pure technical efficiency. Table 3 reveals the operating scale of different water utilities. The scale inefficiency results indicate that only two of the utilities are operating at the optimal scale and seven cities are operating under increasing returns to scale (IRS). But all the remaining cities, that is, 18 water utilities, are operating under decreasing returns to scale (DRS). These results have implications for urban domestic water pricing. Generally, in the public utility pricing literature it is assumed that the utilities are operating under IRS and the marginal cost-pricing rule that ensures economic efficiency is not applied since the full cost is not recovered. These results support the idea that to get efficiency in the operation of water utilities, the water should be priced according to the marginal cost of supply of the water[8]. It is contended that implementing marginal cost pricing is cumbersome in India due because of problems in using historical data, estimating external costs, apportioning joint costs and concerns related to the equity aspect of water supply. Understanding the inherent difficulties of using marginal cost pricing, urban water in India is charged in many ways. A connection charge is imposed, which is a one-time levy, a tax and other rents are paid annually and other consumption charges are paid every month or at a predetermined time (Mathur & Thakur, 2003). In contrast to the above observation made by Mathur & Thakur

[8] Whittington (2003) also observes that many South Asian cities are facing the situation of decreasing returns to scale in operation as they incur high costs to bring additional water into cities.

Table 2. Output-oriented technical inefficiencies of urban water providers in India.

Group	City	Scale efficiency	Pure technical efficiency	Technical efficiency at CRS*
Municipal corporations and government	Bhubaneswar	1.074	1.080	1.160
	Chandigarh	1.471	1.020	1.500
	Raipur	1.025	1.600	1.640
	Greater Mumbai	2.020	1.000	2.020
	Rajkot	1.146	1.780	2.040
	Nagpur	1.750	1.200	2.100
	Pune	2.140	1.000	2.140
	Ahmedabad	2.150	1.000	2.150
	Vadodara	1.510	1.470	2.220
	Vijayawada	1.455	1.560	2.270
	Indore	1.660	1.530	2.540
	Guwahati	2.930	1.000	2.930
	Itanagar	3.210	1.000	3.210
	Nashik	1.769	1.860	3.290
	Bhopal	1.419	2.650	3.760
	Average	1.69	1.32	2.23
Municipal corporations and parastatals	Surat	1.000	1.000	1.000
	Agra	1.000	1.000	1.000
	Meerut	1.187	1.230	1.460
	Amritsar	1.252	1.270	1.590
	Nanded	1.073	1.920	2.060
	Coimbatore	1.210	1.810	2.190
	Ludhiana	1.779	1.310	2.330
	Mysore	1.044	2.280	2.380
	Madurai	1.016	2.480	2.520
	Hyderabad (MCH)	1.849	1.460	2.700
	Visakhapatnam	1.324	2.990	3.960
	Mathura	1.047	7.680	8.040
	Average	1.20	1.82	2.20
Overall average		1.43	1.55	2.21
Overall average (without Mathura)		1.47	1.43	2.11

*CRS, Constant returns to scale.

(2003), our study asserts that data inadequacy could be managed by using the method suggested in this study and the marginal cost pricing principle could be applied in the proposed cases.

To explain the differences in inefficiency scores we classify the utilities according to their management structure. Although the public owns all the water utilities in India, they are managed by different agencies. Categorizing water utilities into different groups according to their management structure is not easy as there is no clear-cut division of responsibilities between the agencies involved in supplying water under the existing arrangements. In the utilities managed by MCs, the municipal authorities themselves are responsible for managing all the activities of planning, designing, construction, implementation, maintenance and O&M of the water supply systems. Similarly, the utilities, which are managed by both MCs and the government, undertake all the activities with varying degrees of

Table 3. Returns to scale observed at various water utilities.

Returns to scale	City
Constant returns to scale (optimal returns to scale)	Surat and Agra
Increasing returns to scale	Raipur, Madurai, Mathura, Bhubaneswar, Nanded, Guwahati and Itanagar
Decreasing returns to scale	Chandigarh, Nagpur, Ahmedabad, Coimbatore, Vadodara, Vijayawada, Mysore, Hyderabad, Nashik, Bhopal, Visakhapatnam, Meerut, Amritsar, Greater Mumbai, Rajkot, Pune Itanagar, Ludhiana and Indore

responsibility. In some cases, PHED does the capital work and the remaining task is undertaken by MCs (e.g. Raipur); in others PHED is assigned to carry out most of the activities leaving very little to be done by the municipal authorities (e.g. Bhopal and Indore). While in others, PHED is the leading agency in managing the water supply system of the city (e.g. Itanagar). Moreover, in some cities, there is some functional autonomy in the management of water utilities, that is, parastatal bodies manage the utilities (e.g. Hyderabad, Agra). In other cities water supply is the responsibility of both parastatal and municipal bodies or is managed by all the three, that is, PHED, municipal authorities and parastatal bodies.

Following this description, we split up the utilities into two groups as 'MCs and government' and 'MCs and parastatals'. We have done this with the conviction that as both MCs and state government agencies are different layers of the government, it is logical to put them into one group. While grouping the water utilities, we assumed that there is some degree of functional autonomy within the group 'MCs and parastatals'. Therefore, we feel it is quite reasonable to put them into a separate category.

Figure 7 shows the performance of water utilities according to their management structures. The overall technical inefficiency scores reveal that the water utilities run by the group 'MCs and parastatals' perform better than the other group.

The decomposition of technical inefficiency results show that the utilities managed by 'MCs and parastatals' perform relatively better in terms of scale efficiency than the other group (Figure 7). But using pure technical efficiency considerations reveal that utilities managed by 'MCs and government' perform better than the other group. The results presented in Tables 2 and 3 also indicate that the scale efficiency is clearly linked to the management of the utility although in both the groups utilities are operating under DRS and IRS. There are seven utilities, four within the group 'MCs and government' and three within the group 'MCs and parastatals' that are operating under IRS. The utilities operating under IRS are small cities in comparison to other cities and the variation in efficiency scores warrants more analysis.

The issue of the type of ownership and its implications for the performance of water utilities has been debated since the publication of the seminal paper by the Crain & Zardkoohi (1978). Although the results are mixed in nature, very often the techniques used for analysing the efficiency are being questioned for their appropriateness and suitability. It must be mentioned here that although the pure form of privatization is yet to see the light of the day as a separate institution providing water in urban India, it can be assumed that there is some degree of corporate managerial discipline, in the group 'MCs and parastatals'. Taking this as granted, our results corroborate the results reached by Crain & Zardkoohi (1978), Bruggink (1982) and Estache & Kouassi (2002). But our results are in contrast to those achieved by Feigenbaum & Teeples (1983), Byrnes *et al.* (1986), Grosskopf (1986), Lambert & Dichev (1993),

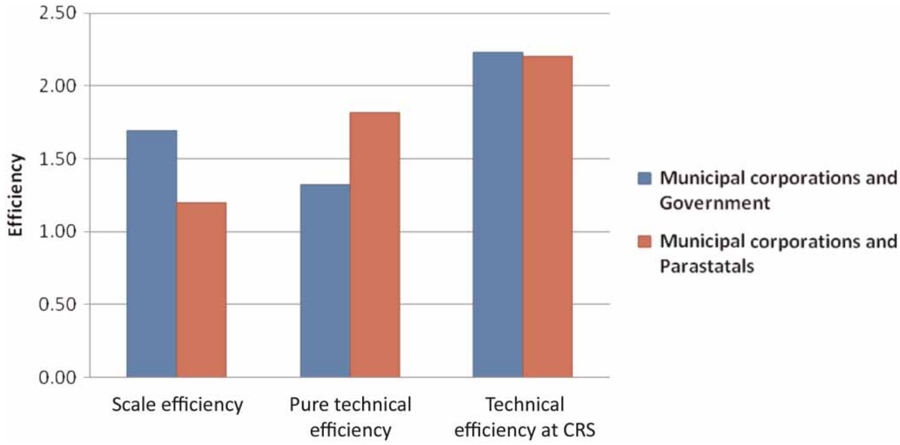

Fig. 7. Average group inefficiency estimates (management structure).

Estache & Rossi (2002) and Kirkpatrick *et al*. (2006) who conclude that there is no significant difference in performance between the private and public operators supplying water.

Again, grouping cities on the basis of population (populations above 1.4 million are in one group and the rest in the other group, as presented in Figure 8), our analysis confirms that less populated cities perform relatively better and have better overall technical efficiency scores. Moreover, decomposition of technical efficiency results suggests that less populated cities are also more scale efficient in contrast to the other group which performs better in terms of pure technical efficiency.

One other issue of concern is to determine the factors underlying the changes in the various measures of efficiency. We expect that specific attributes of an individual utility contribute to its performance. Therefore, to further aid an understanding of the results discussed above and to test the hypothesis whether functional autonomy in management of utilities has affected the various measures of efficiency, we regress various measures of efficiency on utilities specific variables such as its management, water storage capacity and so on. Tobit regression is often used with censored data and is suitable for analysis

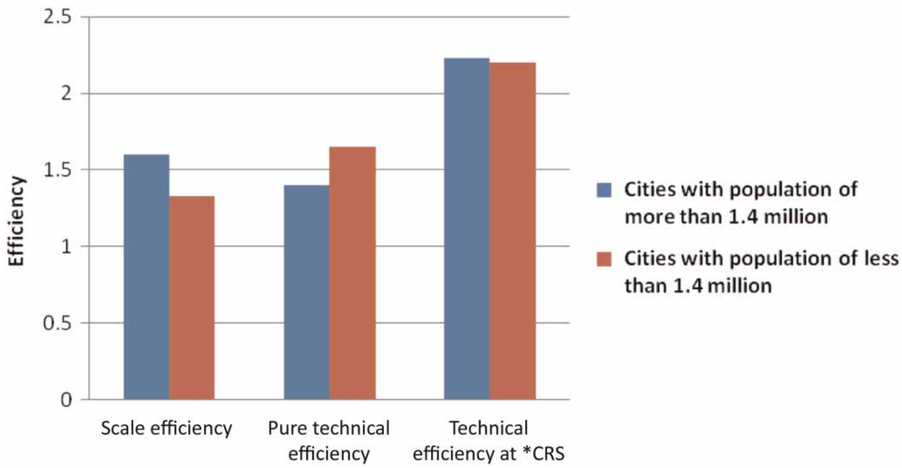

Fig. 8. Average group inefficiency estimates (size of population). *CRS, contant returns to scale.

Table 4. Factors determining technical and scale inefficiency of water utilities.

	Technical efficiency		Pure technical efficiency		Scale efficiency	
Dependent variables	Coefficient	*t*-statistics	Coefficient	*t*-statistics	Coefficient	*t*-statistics
Independent variables						
Intercept	17.866*	3.922	18.602*	5.211	6.370*	3.885
Dummy for management	0.020	0.030	0.196	0.375	−0.822*	−4.046
Log(lpcd)	−1.735**	−2.357	−1.283**	−2.392	−0.516**	−2.011
Log(per capita revenue expenditure)	0.515**	1.936	0.779*	2.903	0.211**	2.151
Log(storage capacity)	−0.668*	−3.577	−1.222*	−5.918	−0.062	−0.875
Adjusted R^2	0.315		0.05		0.272	
Log likelihood	−39.71		−32.11		−19.36	

* and ** indicate that the variable is statistically significant at 1 and 5% level of significance.

of efficiency scores. In the first equation the technical efficiency scores, in the second equation scale efficiency scores and in the third equation pure technical efficiency scores were taken as dependent variables. To examine the relationship between different measures of efficiency and their determinants, we included a dummy for management, that is, 1 for the utilities where parastatals either completely or partially manage the utility, and 0 for others, per capita per day water supplied (lpcd), per capita revenue expenditure and water storage capacity of the utility.

Table 4 provides the parameter estimates of the regressions for the inefficiency indices. The regression results show that three inefficiency indices are significantly affected by most of the independent variables. We find that the variables lpcd and per capita revenue expenditure affect the inefficiency indices negatively and positively, respectively, as expected in all three regressions. It is expected that the utilities that are providing higher lpcd and incur less per capita revenue expenditure will be less inefficient. The water storage capacity of the utilities increases the performance of water utilities, although the coefficient of water storage is not statistically significant for scale inefficiency.

The dummy variable signs are of particular interest and require some discussion. We find that the management variable is not statistically significant for all the three indices. Water utilities with functional autonomy in the management structure are scale efficient. But we find that the functional autonomy in management is not linked to the technical efficiency of the utilities. Here it should be noted that most of the small cities such as Itanagar and Guwahati are managed by the government and municipal bodies. Although the utilities are efficient in terms of pure technical efficiency, they are not fully utilizing economies of scale, that is, they are facing downward sloping average and marginal costs curves. These cities present the case of a pure natural monopoly where the water cannot be priced according to the principle of marginal cost pricing since a firm with economies of scale cannot recover its costs with marginal cost pricing[9].

[9] In the single product case: 'a firm producing a single homogeneous product is a natural monopoly when it is less costly to produce any level of output of this product within a single firm than with two or more firms' (Joskow, 2005). This definition corresponds to the property of sub-additivity of the cost function (Sharkey, 1982), which (in the single product case) is equivalent to economies of scale. Consequently, in the single product case, economies of scale are a sufficient but not necessary condition for natural monopoly (Joskow, 2005).

7. Conclusions

The productivity of water utilities has been an important policy issue for a long time. This has assumed greater significance in the current context of reforms in the structure and functions of the utilities. This paper contributes to that debate by analysing the impact of management on efficiency.

The results of our analysis reveal some interesting insights and corroborate studies carried out on similar lines by Crain & Zardkoohi (1978), Bruggink (1982) and Estache & Kouassi (2002). Grouping utilities under two management structures, that is 'MCs and parastatals' and 'MCs and government', our study establishes that the group 'MC and parastatals' is a better performer in managing the urban water utilities. This supports the argument that management structures with some degree of corporate discipline produce better outcomes. At the same time our study finds contrasting evidence to the findings of Feigenbaum & Teeples (1983), Byrnes *et al*. (1986), Grosskopf (1986), Lambert & Dichev (1993), Estache & Rossi (2002) and Kirkpatrick *et al*. (2006) who conclude that there is no significant difference in performance between the private and public operators in supplying water.

Our results also have implications for the pricing of water. The offshoot of our analysis suggests that as most cities are operating under DRS, marginal cost pricing principles can be followed. This is in contrast to the common pricing practice of utilities having the character of a natural monopoly.

Therefore it can be concluded from our analysis that although it is difficult to make a clear-cut segmentation of the institutions into private and public, nevertheless, assuming a certain degree of functional autonomy that inherently exist in the parastatal bodies, our study affirms that functional autonomy may have the potential to improve water services in developing countries like India. Finally, we note that the results of the study should be read with caution as the data quality provided in the CDPs is poor. Nevertheless, the study provides some important policy-relevant inputs.

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