Performance Benchmarking Analysis of Japanese Water Utilities

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ABSTRACT

Although the Japanese water sector is economically and socially important, few empirical studies are available to help analysts and policy-makers understand the performance patterns in the industry. This study applies non-parametric methods to 5,538 observations on 1144 utilities that supplied drinking water between 2004 and 2007. With a comprehensive census of utilities, the present study controls for a number of factors affecting efficiency: region, prefecture, ownership/governance, water source, vertical integration (purchased water or integrated), peak factor, per capita consumption, customer density, water losses, monthly water charge, outsourcing, subsidies, gross prefecture product, and time. Thus, we are able to derive more comprehensive conclusions regarding efficiency patterns in Japan.

Keywords: Benchmarking; Exogenous variables; Japanese water utilities; Non-parametric methods; Performance

INTRODUCTION

The Japanese water sector is economically and socially important, however not many empirical studies are available to help analysts and policy-makers understand the performance patterns in the industry (some exceptions are the studies by Aida et al., (2008); Mizutani and Urakami (2001); Urakami (2007)).

This paper contributes to the literature by applying non-parametric of data envelopment analysis (DEA) methods to a large sample of Japanese water utilities consisting of almost the entire sector from 2004 through 2007. This corresponds to atypical unique sample of 5,538 observations encompassing 1144 utilities. As far as we know, our study represents the detailed performance benchmarking study carried out for the Japanese water sector. We investigate the influence of exogenous variables (institutional and operational environment) on the performance of Japanese utilities using a recently developed robust technique. The incorporation of exogenous variables (i.e. variables which are beyond the influence of the managers of observations) is fundamental in a performance benchmarking analysis (Witte and Marques, 2010).

Most water services in Japan are supplied by municipalities, but the type of utility ownership and governance arrangements differ: utilities can be owned by villages, towns, cities, prefectures, or cooperatives. Previous studies indicate that there are probably too many utilities of small size—one issue investigated here. In 2007, half of the 1325 water suppliers (end-product distributors without investments in bulk supply) have less than 30 thousand customers. Although each utility must be self-supporting (in terms of cost-recovery) and operate in an efficient manner under the Water Laws, suppliers are actually self-regulated and receive both operating and capital expenditure subsidies. Thus, the impact of subsidies is another issue examined here. In addition, we consider the impact of other factors on efficiency: region, prefecture, ownership/governance, water source, vertical integration (purchased water or integrated), peak factor, consumption per capita, customer density, water losses, monthly water charge, outsourcing, subsidies (totaling ¥42 billion in 2008), and gross prefecture product.

This study measures the efficiency of Japanese water utilities and evaluates the influence of exogenous variables (institutional and operational) on performance. In section 2, we describe briefly the non-parametric techniques applied. Then in section 3 the sample and the results obtained are presented and analyzed. Section 4 digs more deeply into the methodology followed to explain the influence of exogenous variables. Section 5 provides some concluding observations.

PERFORMANCE EVALUATION BY NON-PARAMETRIC TECHNIQUES

The use of non-parametric techniques is increasing as analysts compare performance across decision-units and identify determinants of outcomes (Emrouznejad et al., 2008). According to Berg and Marques (2010) the water sector alone featured 190 papers (articles and reports) through 2009, with about 35% of them applying non-parametric techniques based on DEA.

DEA is a technique based on mathematical programming; it is used to evaluate the productive efficiency of comparable (homogeneous) enterprises (Charnes et al., 1978). DEA builds the non-parametric frontier formed by the union of a group of linear segments (piece-wise surface) which includes the best practice observations.

The relative efficiency measurement is done through the comparison of the observed efficiency compared with that of the other observations forming that frontier. From these frontier observations, the ones that use similar input and output combinations are taken as benchmarks and, simultaneously, become the standards (targets) for the observations being analyzed (where the decision-units are viewed as part of a peer group).

Such non-parametric techniques have a great advantage over other quantitative methods: they let the data speak for themselves (Stolp, 1990). These empirical techniques do not prescribe an underlying functional form for the efficient frontier and they do not define specific values for the weight given decision-units identified as inside the frontier (compared with the least squares criterion). Thus, non-parametric techniques, and particularly DEA, have many advantages. Fried et al. (2008) noted the following benefits: a) identifying an efficient observation group for each inefficient observation with a similar combination of inputs and outputs; b) incorporating easily both multiple inputs and multiple outputs; c) using best practices adoption as comparison elements instead of average values; d) not imposing a functional form for the frontier or for the inefficiency term; e) decomposing efficiency into several components; and f) being conservative, in general (by avoiding the requirement of specific functional forms).

The downside is that the DEA non-parametric technique is deterministic in nature: they assume that there is no noise or atypical observations in the sample (Daraio and Simar, 2007). Therefore, they are very sensitive to the presence of outliers and, so, very demanding with regard to the information required to conduct a comprehensive quantitative analysis (Simar and Wilson, 2004). In addition, the standard techniques do not incorporate errors in variables, nor do they allow for testing statistically the significance of the results or indicate the explanatory power of the specified models. Furthermore, controlling for elements beyond managers' control is important for determining relative performance. For the DEA technique, adjusting for environmental variables is more complex due to the imposition of separability conditions, and depends on the correlation between the inputs and outputs and the exogenous features of the external environment (Cazals et al., 2002).

From the operational perspective, the (historical) inability to make statistical inferences has reduced the usefulness of non-parametric methods. It would be very hard for a regulator (or government ministry), for example, to base a decision on some performance target on DEA scores when the agency is unable able to statistically test the models that were utilized in the regulatory process (Tadeo et al., 2009). Similarly, they would be unable to empirically determine the full impact of exogenous variables. For water utilities, the operational environmental is a major determinant of production and cost outcomes (Carvalho and Marques, 2010).

DETERMING THE EFICIENCY OF JAPANESE WATER UTILITIES

Data and model specification

This section describes the data and model specification. The current case study used a sample of 1144 utilities (5,538 observations) that provided drinking water supply between 2004 and 2007 in Japan.

The model considered three inputs and two outputs. All the monetary variables are expressed in 2007 prices using the CPI. The inputs included capital cost, staff cost, and other operational experiences. Some studies use kilometers of network pipe as a proxy for capital costs. However, here Annualized capital expenses (CAPCOST) were computed by summing depreciation and amortization and interest payments and other financial charges paid. Staff cost was determined by the sum of labor cost and outsourcing expenses. Other operational costs include energy, chemicals, and the other (operational) costs. All the inputs were measured in monetary units. For outputs, we adopted the volume of water billed (in thousands of cubic meters) and the number of customers. Both the input and output variables are used in quantitative water utility studies. Earlier studies published in Japanese utilized similar sets of variables, usually for much smaller samples.

Table 1 presents the summary statistics of the sample used here, covering 2004-2007. We adopted an input orientation which is generally adopted in the water sector (since there is a demand side management policy in this sector and all customers must be supplied).

Table 1. Summary Statistics for the Dataset

	Inputs			Outputs	
	CAPCOS (¥)	Other OPEX (¥)	Staff cost (¥)	Customers (no.)	Billed water volume (10^3 m^3)
Average	750,519	669,051	442,213	87,781	10,324
St. Deviation	3,222,736	3,646,928	2,443,920	399,865	49,107
Minimum	6,455	4,763	5,968	723	161
Maximum	99,756,811	124,435,860	75,448,946	12,494,467	1,529,784
Median	248,652	165,331	104,855	26,585	3,051

All the data except for deflators are taken from the *Year Book of Local Public Corporations*; in FY 2004-2007, published on the website by the Ministry of Internal Affairs and Communications (MIC).

Results

Table 2 presents the results of applying standard DEA to Japanese water utilities.

Table 2. DEA efficiency statistics

	CRS	VRS
Average	0.477	0.559
St. Deviation	0.147	0.178
Minimum	0.134	0.153
Maximum	1.000	1.000
Median	0.453	0.528
Number of efficient observations	39 (1%)	128 (2%)
Number of observations with CRS	728 (13%)	
Number of observations with IRS	1,296 (23%)	
Number of observations with DRS	3,514 (63%)	

We found significant levels of inefficiency (52.3% in CRS model and 46.1% in VRS model) and concluded that most water utilities are operating under decreasing returns to scale (DRS). Indeed, distortions in the water utilities market structure in Japan are responsible for about 15% of inefficiency.

Figure 1 displays the results of efficiency sorted by decreasing number of customers and figure 2 shows the histograms of efficiency of VRS and CRS models.

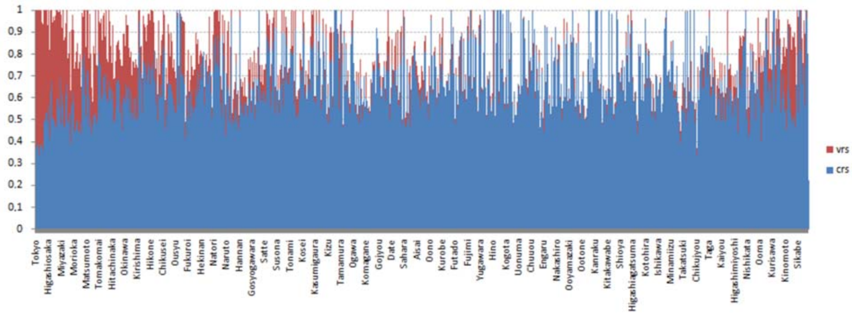


Figure 1. Efficiency scores of Japanese water utilities for the CRS and VRS models (largest to smallest utilities)

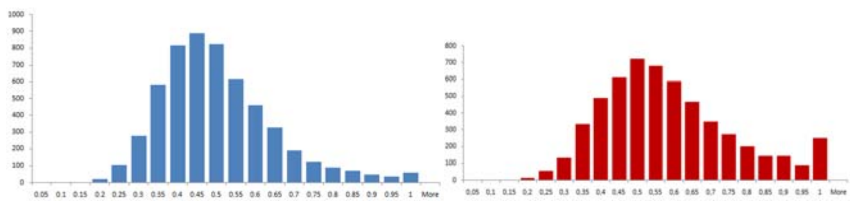


Figure 2 – Efficiency histograms of Japanese water utilities for the CRS and VRS models

Since Variable Returns to Scale is less constraining than the CRS model, the measured inefficiency is a slightly less for the former.

ADJUSTING FOR ENVIRONMENT

Methodology

As stated, it is possible to allow for the inclusion of exogenous (or environmental) variables in efficiency calculations. This characteristic is very important since in most situations the environmental variables have a strong influence on the production process and not considering them in efficiency analysis can lead to biased efficiency estimates (Daraio and Simar, 2005). If the estimates are used by policy-makers for rewarding or punishing utilities, they must control for elements beyond managerial control.

The inclusion of environmental variables is accomplished by constraining the production process to a given value of the exogenous variable (usually called Z). The technique allows the analyst to obtain the efficiencies scores *a posteriori*: taking into account the impacts of exogenous variables.

Obtaining the conditional efficiencies involves the estimation of a non-standard conditional distribution function, which requires the use of smoothing techniques for the exogenous variables. Such smoothing techniques require the adoption of a kernel function and the determination of a bandwidth. In this research, we used the Gaussian kernel function and the likelihood cross validation to obtain optimal bandwidths (Daraio and Simar, 2005).

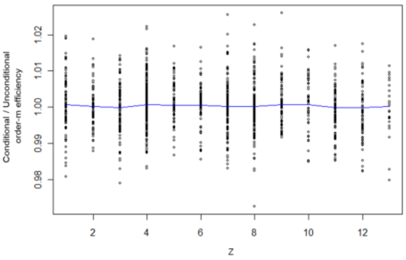
The influence of exogenous variables on the production process is assessed through a smoothed non-parametric regression between the ratio of conditional and unconditional efficiencies (Daraio and Simar, 2005). That is, in an input orientation context, when the non-parametric regression has a positive slope, the exogenous variable is unfavorable to efficiency and if the regression has a negative slope the exogenous variable is favorable to efficiency.

Impacts of Exogenous Variables

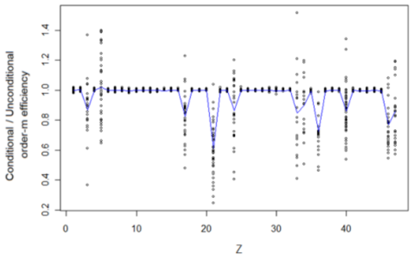
Taking into account Japan's context, we considered 14 exogenous variables that we will describe briefly while pointing out the expected contribution on efficiency and the results obtained. We analyze the influence of the following variables on the efficiency of Japanese water utilities of the: (a) Region; (b) Prefecture; (c) Owner; (d) Water Source; (e) Vertical Integration (purchased water or vertically integrated); (f) Peak Factor; (g) Consumption per Capita; (h) Customers Density; (i) Water Losses; (j) Monthly Water Charge; (k) Outsourcing; (m) Subsidies; (n) Gross domestic product and (o) Time. Customer mix, although important (see Renzetti and Dupont, 2009), is not investigated since these utilities primarily supply residential customers. The results are presented in Figure 3.

Concerning the regions (Japan is divided into 13 regions) it was not possible to find any statistical significance of their influence on efficiency (Figure 3A). Japan is divided into 47 prefectures. Their inclusion in the analysis allowed us to identify those prefectures that had favorable conditions (see Figure 3B).

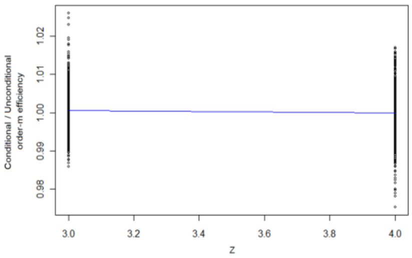
In Japan the density of customers computed by the number of customers per kilometer of pipe length is very high; the nation has very few rural utilities. Although normally this variable is important for network utilities, considering the Japanese market structure, this variable was not significant (Figure D).



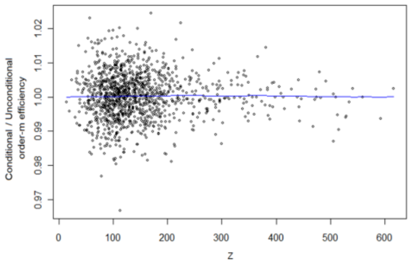
A. Regions



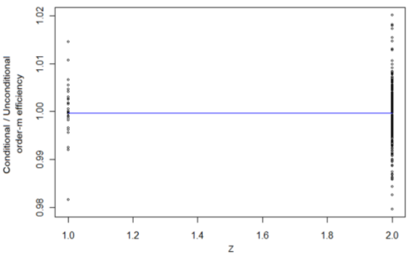
B. Forty-seven Prefectures



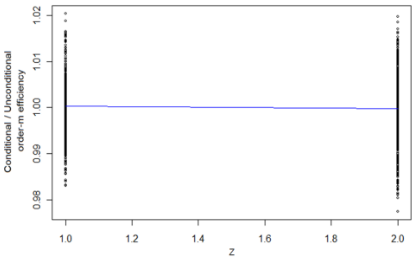
C. Owner of water utilities



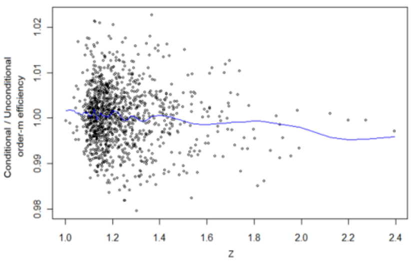
D. Density



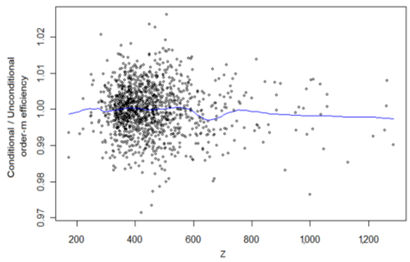
E. Dam vs. Other Sources



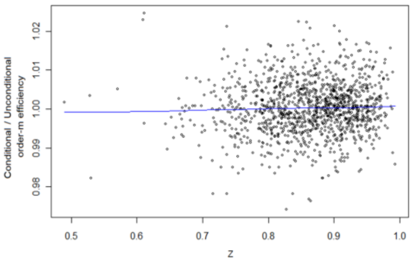
F. Integrated vs. Importing Water



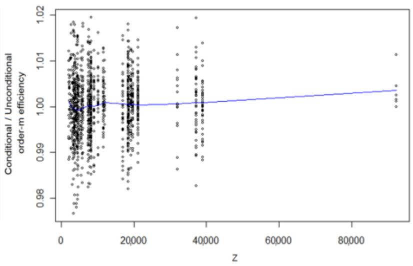
G. Peak Factor



H. Per Capita Consumption



I. Leakage



J. GDP

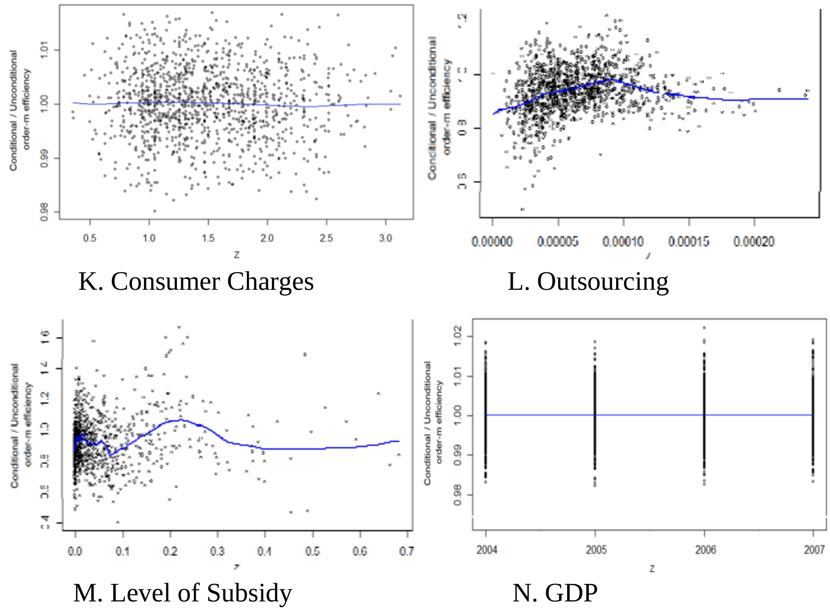


Figure 3. Influence of exogenous variables on efficiency

Owners of water utilities in Japan are divided into five types (prefecture-owned utilities (0.3%), city”-owned utilities (1.3%), city-owned utilities (52.4%), town or village-owned utilities (42.3%) and 49 “wide-ranged cooperative”-owned utilities (3.7%)). Our computations provide evidence of a positive influence the town-villages category compared with having the ownership/governance structure of the cities (Figure 3D). This may be due to the ability of smaller towns to monitor utility performance by less complicated (smaller) operators.

The sources of water supply in Japan are mainly from surface water (72%) and ground water (25%). According to our non-parametric regression, the water source has no influence on water utility efficiency (see Figure 3 D). However, as Figure 3E shows, we found a slight positive influence of vertical integration (the level of confidence was of 90%).

The peak factor (computed as the ratio between the maximum day consumption in one year and the average consumption per day) in Japan in water utilities varies very much. We found that the peak factor has a positive influence on the efficiency of water utilities in global terms (see Figure 3G). This result is a little surprising since it implies that a steady, level load on the system is more expensive to meet than one that is peaked.

According to our sample, the Japanese water utilities have an average of 323.7 liter per customer per day (water billed). On average, increased consumption per capita has a positive influence on efficiency (suggesting that running more water through a given distribution system is not costly). The level of significance of this result is about 93% (see Figure 3H).

As Figure 3I indicates, leakage has no influence on efficiency. This might be because the leakage level is small (an average of 7.5%).

As seen in Figure 3J, we found a positive influence of gross prefecture product up to a certain amount of prefecture GDP and a negative influence after that.

In Japan variations in consumer charges are 10 times greater between the most expensive and the cheapest water utility. The results in Figure 3K indicate that there is no statistically significant positive or negative impact of consumer charges on the efficiency of Japanese water utilities.

We examined whether water utilities that make more use of outsourcing are more (or less) efficient than otherwise. The average percentage of outsourcing costs in Japan is 5.9%. As shown in Figure 3L, the ratio of outsourcing to total operating expenses seems to have a negative influence on the efficiency mainly near the 0.01%, having a positive influence as it tends to 0.02% and to 0%.

Subsidization of water in Japan is very high. The results depicted in Figure 3M suggest that the ratio of subsidy to total operating expenses has a positive influence on the efficiency of the Japanese water utilities as it approaches of the approximately 7% and a negative influence as it approaches 20%. This result warrants more detailed analysis in future research: do (potentially politically-determined) subsidies cause efficiency or inefficiency or are they based on observed patterns of efficiency and inefficiency and designed to improve efficiency?

Concerning the influence of time in the efficiency between 2003 and 2007, we would expect that productivity should increase over time, but the efficiency of firms might increase or decrease, depending on other factors. The results provide evidence that no matter the year under study, there is no influence efficiency of the Japanese water utilities (see figure 3N).

CONCLUDING REMARKS

This research evaluates the efficiency of water utilities in Japan and provides a preliminary exploration of the influence of exogenous variables on measured efficiency. The Japanese data are comprehensive; the access researchers have to data is outstanding compared to many other nations. In a sense, the system represents transparency at its best, and has provided Japanese scholars with the raw material for numerous studies. Of course, the decision-relevance of production function studies depends on how well the basic conclusions are communicated to decision-makers in a clear and authoritative manner. This technical study does not purport to serve as a guide to public policy. Rather, it identifies several areas that warrant greater policy discussion: consolidation vs. disaggregation, current subsidy arrangements, and the long term financial sustainability of water networks in the absence of improved incentives for cost containment.

Efficiency scores can be used for developing internal incentives for managers and for external incentives (for setting cost targets, prices, or subsidies). In the latter case, benchmarking reduces the information asymmetry between managers and those providing oversight (Berg, 2010, p. 114). However, in Japan, the oversight function is missing. The industry basically operates under self-regulation. One lesson from experiences in other nations is that citizen awareness of relative performance puts pressure on managers to reduce costs and improve service quality. However, at present, despite an excellent record on data collection and access, there seems to be no “advocate for efficiency” in the ministerial system.

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