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Efficiency and Ownership in Water Supply: Evidence from Malaysia

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Water supply industries around the world have been radically transformed in the last two decades due to liberalization and/or privatization, and implementation of a new regulatory design. The reforms are with the aim of enhancing efficiency, productivity and quality. Malaysia followed a similar path and experienced water supply industry reforms which began in early 1990. This article assesses the impact of ownership on water supply entities performance with quantitative empirical evidence from Malaysia. The article analyses the efficiency of water supply sector in Malaysia in a multiple input multiple output setting. The non-parametric linear programming framework of Data Envelopment Analysis is utilized to measure the technical and scale efficiency of the water supply entities. The variations of efficiency are observed for different types of ownership and different service areas. The results reveal that, on the overall, private entities outperform the public entities in terms of technical efficiency. The private sector has an average overall technical efficiency score of 86% while the public sectors efficiency score is 70%. The source of inefficiency in the private sector is wholly due to its scale while the public sector is due to both scale and technically inefficiency. However, there is no conclusive evidence that private ownership is more successful then public ownership as there are also technically efficient public operated water supply entities.

Field of Research: Economics

1. Introduction

Water supply industries around the world have been radically transformed in the last two decades due to liberalization and/or privatization, and implementation of a new regulatory design. The reforms are generally with the aim of enhancing efficiency, productivity and quality. Malaysia followed a similar path and experienced water supply industry reforms which began in early 1990. This was with the expectation of improved service quality and efficiency. As a first step to drive the water authorities to improve the quality of their services, to help enhance public accountability and managerial efficiency in pursuit of productivity gains, performance indicators were introduced in the water supply industry in 1994. This also helped to set up performance standards for the water supply industry.

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The measurement of performance of the water utilities is an important and challenging task. Performance measurement helps identify and track progress against goals, compare performance against others and identify opportunity to improve. Performance measurement spurs better performance.

Despite the importance of measuring efficiency, there is scarce literature examining efficiency and the impact of ownership on efficiency in the Malaysian water supply sector. The best source of performance information is the Malaysian Water Industry Guide (MWA, 2006) published annually which provides a range of performance indicators such as operating and maintenance cost per connection, average consumption per domestic account/month and transmission and distribution storage capacity for each water utility. However, these indicators are partial performance measures, which typical involve single input or single output indicators.

Thus, the aim of this study is to fill the gap by carrying out a quantitative empirical analysis of efficiency in the Malaysian water supply sector. The theoretical aim is to develop a comprehensive measure of performance that integrates several performance indicators (inputs and outputs) to compute a single measure of efficiency. This achieved by using the non-parametric linear programming technique of Data Envelopment Analysis (DEA). The empirical aim is to benchmark water supply entities in Malaysia in their use of multiple inputs to produce multiple outputs and to test whether different ownership forms have a different effect on efficiency.

The rest of the paper is structured as follows: Section 2 provides a review of the literature on efficiency studies in the water sector. Section 3 provides the background information on the Malaysian Water Supply Industry and gives a summary of the current performance evaluation system. Section 4 describes the methodology utilized in this study i.e. the Data Envelopment Analysis (DEA) technique. Section 5 presents the data and the model used in the analysis and Section 6 presents the empirical results. The final section draws some conclusions.

2. Literature Review

The privatization and regulation of the water sector has attracted considerable attention by public and academia on various issues. There is now an extensive literature that reflects this growing interest. Mainstream objectives of water sector efficiency analyses are the investigation of the relation between efficiency and administration and/or ownership type, comparative water sector efficiency to establish rankings, and evaluation of efficiency after reform processes. This review looks at the literature in the developed and the developing countries.

Literature in the developed world: Scholars in the United States and the United Kingdom have given considerable attention to the water sector. The issue of efficiency of public versus private ownership has been long debated in the US since the late 1970's. The first studies were by Crain and Zardkoodi (1978) and Bruggink (1982) who estimated a Cobb-Douglas cost function, Byrnes, Grosskopf and Hayes (1986) who used the linear programming technique known as data envelopment analysis (DEA) and Teeples and Gyler (1987) who provided a comparison of models in the earlier studies. A second round of studies surfaced in the mid 1990's. Lambert and Dichev (1993) conducted a comparative analysis of private and publicly owned water utilities using data on 238 public and 32 private firms in America. They measured technical, allocative and scale efficiency using DEA. The single output variable used was total water delivered, while four input variables were used i.e. annual labour use in hours, British thermal units of energy used, value of material inputs used and the value of capital. They found that technical inefficiency was the main source of inefficiency and there are no significant differences between private and public owned utilities. Bhattarcharyya, Parker and Raffie (1994) and Bhattarcharyya et al. (1995a, 1995b) estimated econometric cost functions and investigated at a number of alternative methodological approaches, such as (i) specifying a short run cost function; (ii) estimating the cost function in a system with first order equations; (iii) estimating a shadow cost system to reflect possible deviations from cost minimizing behavior; (iv) estimating the cost function using stochastic frontier techniques and (v) including quality variables such as system disruptions and water loses in the model. Wallsten and Kosec (2005) compared the private and public water utilities in the US by including several dimension of quality in their analysis.

With the privatization move in the early 1990's in the UK, scholars began using the UK data to conduct several studies. These include the Stochastic Frontier analysis (SFA) cost frontier study by Lynk (1993); the comparison of the results of DEA and regression analysis in Cubbins and Tzanikadis (1998); the cost function study of Hunt and Lynk (1995) and Ashton (2000); the DEA studies of Thanassoulis (2000a, 2000b); the Tornqvist total factor productivity (TFP) index and the SFA cost frontier study of Saal and Parker (2000, 2001). Saal and Parker (2000, 2001) evaluated the impact of privatization and regulation on productivity growth and the total cost of the water sector in England and Wales. They emphasized the issue of quality in the water sector and used quality-adjusted outputs. More recently in 2006, Saal and Parker (2006) employed a quality adjusted panel input distance stochastic frontier to estimate productivity growth of the water sector in England and Wales over the period 1993 to 2003.

Literature in developing world: In recent years, a number of studies have appeared in the developing countries. These are the cost function study of French water supply businesses by Garcia and Thomas (2001); the DEA study of Peru water utilities by Alva and Bonifaz (2001); the stochastic cost frontier analysis of water supply industries in Asian countries by Estache and Rossi

(2002); the DEA study of Mexican water supply businesses by Anwandter and Teofilo (2002); the DEA study of Brazilian water sector by Tupper and Resende (2004) and Seroa da Motta and Moreira (2004); the DEA study of Spanish water utilities by Garcia-Valinas and Muniz (2007) and the DEA studies incorporating quality indicators of Peru water sector by Lin and Berg (2008) and the Spanish water utilities by Picazo-Tadeo et al. (2008). Estache and Rossi (2002) who examined the effects of ownership on utility performance found significant differences between private and public water utilizes, with the privately owned utilities achieving significant gains. In contrast Kirkpatrick et al. (2006) found no significant differences between ownership types in African water utilities using the DEA analysis. This was also supported by Seroa da Motta and Moreira (2004).

From the review it is apparent that the existing research literature on the measurement of efficiency in the water sector is largely based on the experience of developed countries such as the United Kingdom and the United States. Increasingly, more studies on efficiency levels in the water sector are being carried out in developing countries such as Brazil, Peru, Mexico and Spain. Cross-countries studies on the relationship between ownership and efficiency have also become increasingly popular. The two most widely used methods of in these studies to estimate efficiency in the water sector, namely Data Envelopment Analysis (DEA) and econometric analysis based on the estimation of stochastic production frontier models.

3. Malaysian Water Supply Industry Structure

Water services in Malaysia cover both water supply (clean water operations) and sewerage services (dirty water operations). In the past water supply was under the Ministry of Works and sewerage services are the responsibility of the Sewerage Services Department under the Ministry of Housing and Local Government. On March 2004, the newly created Ministry of Energy Water and Communications undertook the management of the country's water supply and sewerage services under one roof. However, the water supply and sewerage services are not integrated unlike many other countries and are the responsibility of different organisations. Our study focuses on the water supply sector. Water supply services involves three stages: (a) the abstraction of water from dams, rivers or ground, (b) the treatment of water extracted to make it usable and (c) the distribution of treated water from the water treatment plants to the consumer.
Historically, under Malaysia's Federal Constitution the respective States in Malaysia is responsible for their water supply services. The treatment and distribution of water in the states is undertaken by state agencies either by the State Public Works Department, State Water Supply Department or State Water Supply Board. Since early 1990s, many states have allowed greater private sector participation in the sector through privatization (Selangor, Pulau Pinang, Johor and Kelantan) and corporatization programs (Terengganu and LAKU) to improve the quality of water supply services. For these states, water supply

services are provided by State Water Supply Corporation or Company and private companies which are monitored by states water supply regulators. The privatization is done through concession agreements. In addition, the water tariffs differ from state to state and most states experience high non-revenue water (NRW). The lack of coordination among various stakeholders, ineffective regulatory structure and poor enforcements, and capital expenditure constraints let to restructuring process in early 2003 by the Federal Government to create a more effective and efficient Water Services industry. The Federal Constitutions was amended in January 2005 whereby water supply services on treatment and distribution transfer to a joint responsibility with the Federal Government. The Federal Government involvement in the state water supply services are in the areas of regulating the service providers and the provision of fund for the maintenance and expansion of water supply services. The National Water Services Commission (NWSC) Act and Water Services Industry Act (WSIA) were established to provide framework and regulate the water services. Both the legislation paved the way for the establishment of the Water Asset Management Company (WAMCo) as the government agency to hold the Facility License under the WSIA and facilitate process of transformation into new water supply industry regime by managing existing water asset and developing future assets. A centralized national economic regulator, The National Water Services Commission (or *Suruhanjaya Perkhidmatan Air Negara*, SPAN), was formed in March 2007 to regulate water services industry including sewerage services, irrespective of government or private ownership, whilst the management of water resources remains within the jurisdiction of the State Governments.

In fact, performance indicators were introduced in the water supply industry in Malaysia in late 1994 as a first step to drive the water authorities to improve the quality of their services, to help enhance public accountability and managerial efficiency in pursuit of productivity gains, besides helping to set up performance standards for the water supply industry. In 2000, The Malaysian Water Association (MWA) took the responsibility of collecting and the statistics and key performance indicators of water utilities and publishing them in the Malaysia Water Industry Guide. Since then, it has become an annual publication. There are 33 performance indicators grouped into four area of performance i.e. physical, operational, service and financial performance indicators.

4. Methodology and Model

4.1 The Data Envelopment Analysis (DEA) technique

In this study, the Data Envelopment Analysis (DEA) approach is used to estimate the levels of efficiency of Malaysian water distribution companies in 2005. DEA measures the comparative efficiency of several homogeneous decision making units by aggregating multiple performance indicators into a single framework for identifying best practice.

The envelopment form of the input-oriented constant returns to scale (CRS) DEA model following CCR (Charnes, Cooper and Rhodes,1978) for the i-th firm is specified as:

$$\min_{\theta,\lambda} \theta,$$

$$\text{Subject to:} \quad -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0, \tag{1}$$

Where θ is the input technical efficiency score having a value $0 \leq \theta \leq 1$. If the θ value is equal to one, this indicates that the region is on the frontier. The vector λ is an *N*x1 vector of weights that defines the linear combination of the peers of the i-th firm. The linear programming problem needs to be solved *N* times (i.e. for each decision making unit) and a value of θ is provided for each firm in the sample. The variable returns to scale (VRS) DEA model is defined by adding the constraint (Banker, Charnes and Cooper, 1984):

$$\Sigma\lambda_i = 1 \tag{2}$$

Because the VRS DEA is more flexible and envelops the data in a tighter way than the CRS DEA, the VRS TE score is equal to or greater than the CRS or 'overall' technical efficiency score. Under the VRS model a company with an efficiency score of less than unity is considered as neither technically efficient nor scale efficient. Otherwise, if the organization receives a unit efficiency score, it is pure technically efficient but may not be scale efficient.

We can measure the scale efficiency (SE) of the i-th firm as:

$$SE_i = \frac{TE_{i,CRS}}{TE_{i,VRS}} \tag{3}$$

Where SE = 1 implies scale efficiency and SE < 1 indicates scale inefficiency. However, scale inefficiency can be due to the existence of either increasing or decreasing returns to scale.

The efficiency scores in this study are estimated using the computer program, Efficiency Measurement System, EMS Ver. 1.3, developed by Professor Holger Scheel, University Dortmund (Scheel, 2000).

4.2 Data and Model Specification

Data for the study is obtained from the *Malaysia Water Industry Guide 2006* published annually by the Malaysian Water Association in collaborations with the Water Supply Department (under the Ministry of Energy Water and Communications). Data was collated from information provided by the 11 state Water Supply Authorities and the 6 privatized/corporatised water companies across Malaysia. The data produced in the *Malaysia Water Industry Guide 2006* publication is detailed and comprehensive. It contains operational, financial, service quality and infrastructure data. Additional data on the supply area of the water companies was obtained from *Statistics Handbook of Malaysia (2006)* which provided the area of the states and federal territories in Malaysia. The supply area of Kuching, Sibu and Laku was obtained directly from the Kuching Water Board, Sibu Water Board and Laku Management respectively. Annual data on the 17 water entities from the year 2005 is used for the analysis as this is the most recent available information.

The water entities provide water production and distribution services which is the extraction, treatment and transportation of a certain amount of water of a certain quality over a certain distance between a treatment plant and a water consumer such that the demands of consumers are met. From the activities of the water entities described above it is apparent that the key outputs of the water distribution business is its service quality, the quantity of water delivered to customers and the number of customers. The inputs that are required to meet these outputs are the costs associated with building, maintaining, operating and refurbishing the pipe, pumps, treatment plants and storage which make up the network. Thus, the operating costs and capital costs are inputs into this process. However, since a monetary measure of capital costs is not available, we use the physical measure of the 'network length' as a proxy.

To account for the constraints of the exogenous operating characteristics of the different companies' environment, we use the area of the companies' service territory. Service area proxies' customer sparsity and combined with customer numbers reflect customer density. A higher dispersion of customers might lead to higher operating expenditure associated with water distribution due to the need for more pipe infrastructure per connection. Quality of service is another important output of water supply services. The volume of non-revenue water (NRW) is an indicator of the technical quality of service. The NRW measures the percentage of water wasted or loss mainly due to leakage, pilferage, meter under registration and system maintenance and firefighting.

The selection of the data in this study is based on the cost drivers in the industry, the review of past literature in water efficiency studies, the availability of data and the limitations due to the small sample size in our study. The model used to

benchmark the efficiency of the water companies and the summary statistics are provided in Table 1.

Table 1: The DEA Model Specification and Summary Statistics 2005

	Variable	Mean	Standard Deviation	Minimum	Maximum
Inputs	Operating Expenditure (RM)	200,931,551.4	356,102,214	17,953,773	1,510,933,082
	Network Length (km)	5,703	4,211.58	449	13,314.18
	Volume of non-revenue water (m^3)	90,266,194.06	122,613,736	3,161,753	522,679,919
Outputs	Volume delivered (m^3)	157,998,217.7	195,616,586	10,343,247	838,040,081
	Number of connections	328,436.24	365,904	12,436	1,483,000
	Service area (km^2)	18,519	29,045.42	92	105,864

6. Empirical Results

The model is estimated for the 17 utilities for CRS and VRS. Table 2 shows the descriptive statistics of the efficiency scores for the full sample as well as separately for each group of ownership. The individual efficiency scores are given in Table 3. For the whole sample, the mean overall technical efficiency is 71.3%. The mean overall technical efficiency scores of the public water companies are very close to the sample mean, while the private water companies are operating at a higher level of efficiency. The mean scale efficiency of the whole sample in 87.3% suggesting that there are some companies that are not operating at the optimal scale and scale inefficiency may be a source of overall inefficiency. This is apparent in the private companies where they are almost 100% technically efficient and thus their inefficiency is wholly due to their scale of operations.

Table 2: Descriptive Statistics of Efficiency Scores

	Number of Companies	Mean	Standard Deviation	Minimum value	Maximum value
All Companies					
OTE	17	0.71283	0.26689	0.26500	1.00
PTE	17	0.83065	0.24706	0.3005	1.00
SE	17	0.87300	0.20792	0.2825	1.00
Public Companies					
OTE	11	0.70235	0.21233	0.26689	1.00
PTE	11	0.84359	0.22228	0.24706	1.00
SE	11	0.87812	0.16669	0.54210	1.00
Private/Corporatised Companies					
OTE	6	0.86262	0.28727	0.28250	1.00
PTE	6	0.99870	0.00291	0.99350	1.00
SE	6	0.86359	0.28742	0.28250	1.00

OTE= overall technical efficiency
PTE= pure technical efficiency
SE= scale efficiency

As seen from Table 3 below, there are 5 water companies with a unit overall technical efficiency score. The rest 12 water companies are overall technically inefficient. The number of technically efficient water companies increase to 9 under the variable returns to scale technology, suggesting that 4 water companies are measured as technically inefficient solely because of scale inefficiency.

The overall technical efficiency scores presented in Table 2 and 3 indicate the potential for companies to reduce inputs while maintaining existing outputs. The efficiency scores for the companies indicate the presence of and extent of inefficiency of input use. For example, on average, the companies are 71.3% efficient. This suggests they could reduce their inputs, on average by about 28.9%. Selangor has the biggest potential to reduce inputs by as much as 71.8% as it is substantially below the efficiency frontier.

Table 3: Efficiency Scores of Water Entities

Company	Ownership	OTE	PTE	SE
Kedah	Public	0.98016	0.60470	0.98016
Sarawak	"	1.00000	1.00000	1.00000
Perlis	"	0.75510	1.00000	0.75510
Labuan	"	0.54210	1.00000	0.54210
Pahang	"	0.97360	0.48860	0.97360
N.Sembilan	"	0.98353	0.47370	0.98353
Sabah	"	0.88186	0.30050	0.88186
Perak	"	1.00000	1.00000	1.00000
Melaka	"	0.99934	0.75950	0.99934
Kuching	"	0.93333	0.52950	0.93333
Sibu	"	0.61034	0.97110	0.61034
P.Pinang	Private	1.00000	1.00000	1.00000
Terengganu	"	1.00000	1.00000	1.00000
Selangor	"	0.28250	1.00000	0.28250
Johor	"	1.00000	1.00000	1.00000
Kelantan	"	0.90065	0.99350	0.90065
LAKU	"	0.99840	1.00000	0.99840

7. Conclusion

This paper has benchmarked the water supply entities in Malaysia to compare their performance with one another. To our knowledge, this is the first published set of comprehensive performance measures for the Malaysian water industry. The DEA methodology is employed using both the constant returns to scale and variable returns to scale assumption to provide measures of technical and scale efficiency for the 17 water entities in Malaysia in 2005. The results reveal a substantial level of dispersion in technical efficiency between companies within the sample and the average firm has a overall technical efficiency 71.3%. There is substantial potential operating expenditure savings across all the companies amounting to over 98 billion RM calculated on the basis of the efficiency score. We found that, on the overall, private entities outperform the public entities in terms of technical efficiency although both sectors are scale inefficient. The private sector has an average overall technical efficiency score of 86% while the public sectors efficiency score is 70%. The source of inefficiency in the private sector is wholly due to its scale while the public sector is due to both scale and technically inefficiency. However, there is no conclusive evidence that private ownership is more successful then public ownership as there are also technically efficient public operated water supply entities.

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