Institutions and Economies
Vol. 9, No. 3, July 2017, pp 21-49

Restructuring to Improve Water Services in Malaysia

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Abstract: *The regulatory structure of the Malaysian water services industry is complex as both the state and federal authority manage water supply at the state level. In 2008, the Federal Government restructured the water industry and centralised the water management of the state government by establishing SPAN (National Water Services Commission) and PAAB (Water Asset Management Company). The objective of SPAN and PAAB is to improve the efficiency of water operators in Peninsular Malaysia including Labuan. Therefore, this study aimed to measure the level of efficiency of the state's water operators before and after the restructuring, and also to determine the factors that affect the level of efficiency of the state's water operator. DEA approach (Data Envelopment Analysis), and Malmquist index were used to measure technical efficiency and productivity of the operator over the period 2000-2013. The DEA score showed that the sector's mean technical efficiency was 73%, and only 42% of the state water operator showed an increasing in efficiency score. Penang's water operator was the most efficient with a score of one over the study period. Total Factor Productivity analyses show that the water industry lags in the area of technology and inadequate capital. SPAN and PAAB also need to review their current key performance indicators in order for the latter to improve the efficiency of the operators.*

Keywords: *Malaysian water sector, efficiency, SPAN, DEA, Malmquist Index*
JEL Classification: L51

Article received: 22 December 2016; Article Accepted: 11 May 2017

1. Introduction

The water industry in Malaysia has experienced dramatic changes with a remarkable improvement in water services over the past few decades (Malaysia Water Association [MWA], 2005). Due to rapid population growth, industrial and agriculture development, demand for water has increased. The Malaysian water sector suffers from operational inefficiency, ineffective governance and regulation, budgetary constraints and poor environmental performance (Kim, 2012). Its operational inefficiency is caused by first, the inability of water utilities to reduce the high volume of non-revenue water and second, the tariff rates are below cost. These have undermined the industry's ability to generate enough revenues to sustain its

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operations and increase efficiency. In addition, the tariff structure has contributed to revenue shortfall leading the industry to be unable to cover costs of abstraction, purification and transportation (Kim, 2012). Political and (fear of losing votes) and socio-economic reasons (promoting equity and accessibility) inhibited state governments from implementing a full cost recovery model in 75% of public water departments (MWA, 2005). In the federal territory of Labuan and the state of Sabah, the prevailing tariffs had been in place since 1982 without any revision. In 2007, more than half of the country's water utilities recorded a deficit in their balance sheet (MWA, 2008).

Ineffective governance and regulation along with inefficient water management have led to water shortage. Furthermore, deterioration in the quality of water creates socio-economic problems to consumers (households and industries) (Mahmoudi, Fathi, Sajadifar & Shahsavari, 2012). Concerted efforts to reform and transform the water industry in Malaysia began in 2006 with the introduction of Water Services Industry Act (WSIA) by the Federal Government and the setting up of National Water Services Commission (SPAN) and Water Asset Management Company (PAAB) in 2007. The objectives of the restructuring in the water services industry in Malaysia are to regulate, supervise and monitor the water services industry including sewerage services. "Asset Light Model" was introduced by PAAB to provide fund for capital expenditure in water services industry. Hence, this paper aims to measure the efficiency of water services, pre-and post-SPAN and PAAB.

1.1 The Water Services Industry in Malaysia

Prior to the establishment of SPAN and PAAB in 2006, treatment and distribution of water in Malaysia was under the state public works department (PWD). Following the privatisation of water supply in 1983, some states have named it water state department (WSD) or water supply board (WSB). In the 1990s, some states have corporatised or privatised their water operators (see Table 2). Thus, policies related to water at the state level is different based on the operators. Studies have shown some states are more efficient than others in managing their water resources (Lee & Lee, 2009; Munisamy, 2009), while others face a high burden of debt with the federal government because their revenue cannot cover their operating cost (MWA, 2005) Table 1 shows the agencies involved in distribution of water supply in Malaysia.

Table 1: Regulatory Body in Malaysian Water Supply

Agency Name	Task	Description
Federal Government	Policy matters	Development of a holistic water policy for the country by setting policy direction.
State government	Water resources matters.	Manage existing water basins with the view of protecting the quality of raw water and identifying new water basins when required.
National Water Resources Council (NWRC)	Governance matters	Ensures coordination with the various State Governments in the management of the water resources.
SPAN (Commission of Malaysian Water Services)	Regulatory matters	Regulate the whole water industry based on the policy directions set out by the Federal Government. Promote and efficiency driven regime
Ministry of Telecommunications, Energy and the Green Environment	Related to energy, communications, postal and water	Responsible for administering, monitoring and managing.

Source: MWA (2009).

SPAN, established in 2006, is a regulatory body to manage the water supply and sewerage services in Peninsular Malaysia and Federal Territories of Putrajaya and Labuan. It regulates all agencies involved in the water supply and sewerage services through the Water Services Industry Act 2006 (Act 655) which was enforced on 1 January 2008 (refer to Table 2). These include public water supply and sewerage services operators, private water supply and sewerage services operators, water supply and sewerage contractors, permit holders and suppliers of water and sewerage products. The SPAN also recommend reforms to the water supply and sewerage services laws as well ensure productivity of the water supply and sewerage services industry. Additionally, it monitors operator compliance with stipulated standards, contractual obligations and relevant laws and guidelines and to increase concerted efforts towards improving the operational efficiency of the industry, in particular the reduction of non-revenue water through short-term, medium-term and long-term programmes.

Table 2: Water service operator before and after restructuring (SPAN)

Before SPAN			After SPAN	
State	Corporate	Private	State	Operator
Water state dept. • JKR Perlis • JKR Sarawak **Water state dept.** • Jab. Bek. Air Negeri Sembilan • Jab. Bek. Air Pahang • Jab. Bek. Air Labuan • Jab. Bek. Air Kedah • Jab. Air Sabah **State water authority** • Lembaga Air Perak (LAP) • Lembaga Air Sibu • LembagaAir Kuching	*Syarikat Air Terengganu Sdn. Bhd*. (SATU) *Syarikat Air Melaka Berhad* (SAMB) LAKU Management Sdn. Bhd (covering Miri, Bintulu, Limbang in Sarawak)	**Treatment and Distribution** • Air Kelantan Sdn. Bhd. (AKSB) • Perbadanan Bekalan Air Pulau Pinang (PBAPP) **Treatment only** • SPLASH • Puncak Niaga (PNSB) • ABASS • Equiventure Sdn Bhd (ESB) • Southern Water Corp. (SWC) • Metropolitan Utilities (MUC) **Distribution only** • Syarikat Bekalan Air Selangor (SYABAS) • SAJH	Johor	Syarikat Air Johor Holdings Sdn Bhd (SAJH)
			Kedah	Syarikat Air Darul Aman (SADA)
			Kelantan	Air Kelantan Sdn Bhd (AKSB)
			Malacca	Syarikat Air Malacca Berhad (SAMB)
			N. Sembilan	Syarikat Air Negeri Sembilan (SAINS)
			Pulau Pinang	Perbadanan Bekalan Air Pulau Pinang (PBAPP)
			Pahang	Pengurusan Air Pahang Berhad (PAIP)
			Perak	Lembaga Air Perak (LAP)
			Perlis	Syarikat Air Perlis (SAP)
			Selangor	Syarikat Bekalan Air Selangor (SYABAS)
			Terengganu	Syarikat Air Terengganu (SATU)
			Labuan	Jabatan Bekalan Air Labuan

Source: MWA (2010).

Water Asset Management Company (WAMCO) or *Pengurusan Aset Air Berhad* (PAAB) is a wholly owned company of the Ministry of Finance. Incorporated in 5 May 2006 with the objective of being the holding company for the nation's water assets, PAAB's primary responsibility is to develop the nation's water infrastructure in Peninsular Malaysia and the Federal Territory of Labuan. This is achieved through competitive financing sourced and obtained from private financial markets. The water assets are then leased to water operators licensed by the industry regulator (SPAN) for operations and maintenance. The PAAB is also tasked to assist SPAN to restructure the nation's water industry to achieve the Government's vision for efficient and quality water services. The PAAB will first take over existing water assets which are currently owned by either the State Government or private water concessionaires. The state water operators (Service Licence) will then lease the water assets from PAAB (Facilities Licensee) for operation and maintenance as the States will continue to be responsible for the provision of water supply services. Thereafter, PAAB will be responsible for building any new water infrastructure required by the States in addition to sourcing and financing for the development of these new assets. As a result of this exercise, the State Governments will be relieved of the burden to fund the construction of new water assets, which requires enormous capital. The state water operators will also become asset-light, and can focus solely on improving the efficiency of their operations and services to the consumers.

Under the new regulatory framework, there is a separation of responsibilities between water asset owners and water operators. State water operators will no longer be responsible for developing water infrastructure so that they can concentrate solely on providing water services to consumers and improving their operational efficiency. The responsibilities of developing water infrastructure and funding will be transferred to PAAB (PAAB, 2006).

This translates into efficient services and better quality water supply for consumers. For the state government, they are relieved of the heavy financial burden to develop water assets and relieved of settling loan to the Federal Government. State water operators can focus solely on providing water treatment and distribution services, and concentrate on achieving operational efficiencies. Thus, state operators can work towards full cost recovery and financial independence in the long term. The federal government will be relieved of the obligation to provide funding to states for the construction of new water infrastructure and there will be a uniformly regulated water services industry (SPAN, 2008). One of the main focus of restructuring is to achieve efficiency by reducing non-revenue water by 25% for state by 2020.

1.2 Non Revenue Water

Non-revenue water (NRW) is the difference between the volume of water put into a water distribution system and the volume that is billed to customers. It comprises three components: physical (or real) losses, commercial (or apparent) losses, and unbilled authorised consumption. Physical losses comprise leakage from all parts of the system and overflows at the utility's storage tanks. They are caused by poor operations and maintenance, the lack of active leakage control, and poor quality underground assets. Commercial losses are caused by customer meter under registration, data-handling errors, and theft of water in various forms and the unbilled authorised consumption which includes water used by the utility for operational purposes and firefighting, as well as free water supply to certain consumers (Salleh & Malek, 2009).

The NRW is one of the major issues affecting water utilities in the developing world because it will seriously affect the financial viability of water utilities through lost revenues and increased operational costs. A high NRW level is normally a surrogate for a poorly run water utility due to lack of governance, autonomy, accountability, and technical and managerial skills necessary to provide reliable service to their population (Kingdom, Liemberger, & Marin, 2006).

2. Literature Review

Farrell (1957) drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. He proposed that the efficiency of a firm relates to its technical efficiency, which reflects the ability of the firm to obtain maximal output from a given set of inputs and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology (Coelli, Rao, O'Donnell & Battese, 1998). The two principle methods are Data Envelopment Analysis (DEA) and stochastic frontiers which involve mathematical programming and econometric methods respectively (Coelli et al., 1998).

Scholars have used DEA analysis in measuring efficiency in public sector which included hospital, education sector, university, water services, zakat management, bank services and many more. The DEA has been used to measure efficiency in water services for developed countries and less developed countries which includes Malaysia. Crain and Zardkoohi (1978), Norman and Stoker (1991), Lambert, Dischev and Raffiee (1993), Bhattacharyya, Harris, Narayanan and Raffie (1995) and Aubert and Reynaud (2005) used DEA to measure efficiency of US water services. In the UK, OFWAT (2010) used DEA to evaluate capital expenditure cost for the production, Cubbin and Tzanidakis (1998) used regression and DEA as a tool to measure efficiency, Thanassoulis (2000a; 2000b), Saal & Parker. (2006), Erbetta and Cave (2006), Saal, Parker and Weymar-Jones (2007) and Byrnes, Crase, Dollery and Villano (2010) used DEA to compare efficiency between public and private ownership. In Malaysia, studies on water service efficiency are limited and which compared public and private water services. Among them are Lee and Lee (2009), Munisamy (2009) and Lee, Tan and Lee (2014) and Kamarudin, Ismail and Ramli (2016). Their finding showed that the private sector was more though only the privatised company in Pulau Pinang was efficient while Kelantan, Terengganu and Johor lagged compared with Perlis which is fully government owned company. Beginning from 2008, all the states have corporatised their water supply services (see Table 2). Therefore, this paper will measure the efficiency of all states focusing on the shift from decentralisation to centralised policy. Under SPAN and PAAB, each state would get the same treatment regardless. Thus, this paper will try to measure efficiency score by comparing their performance before and after the restructuring.

2.1 Data and Method

Data was obtained from the Malaysian Water Industry Guide published by Malaysian Water Association (MWA), it covered the period between2000 and 2014. Thanassoulis (2000b), used operating expenditure as an input while variables such as the number of supply connections, the length of the main (reflecting the dispersion to clients) and the amount of water delivered as were used as outputs in the modelling of water distribution.

Water operators are tasked to provide clean treated water and distribute it to customer as well as provide services which include the extraction, treatment and transportation. Key outputs of the water distribution business are its service quality, the quantity of water delivered to customers and the number of customers while 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 operation expenditure (RM), and capital costs (RM) are inputs to this process. However, since a monetary measure of capital costs is not available, this paper uses the physical measure of the 'network length' (km) as a proxy (Munisamy, 2009).

OFWAT (UK-Water Service Regulation Authority) uses operating expenditure as an input and number of connection, length of main and water delivered as outputs while Battacharyya et al., (1995) used water sales as a single output. Kamarudin et al., (2016) used NRW as the undesirable output by using Directional Distance Function to evaluate efficiency because conventional DEA only deals with input and desirable output without include undesirable output.

2.2 Data Envelopment Analysis (DEA)

In this paper, DEA is used to estimate the technical efficiency of water services pre- and post- restructuring. It assesses technical efficiency (TE) by using either input or output orientation approach. In this paper, constant returns to scale is adopted because water services is a monopoly This is because the scale size of the water companies is largely inherited and is likely to be outside the managerial control in the short-run. Thannassoulis (2000a), argued that scale size is likely to be dependent on contextual variables such as the population and the dispersion of the population. In the case of water utilities, where output as measured by the water delivered is price inelastic and inputs such as labour cost and materials costs may be adjusted accordingly and thus, the latter is more suitable.

According to Coelli et al. (1998), constant return to scale (under input orientation) can be defined as:

$$\min\_\theta\lambda\ \theta.$$

subject to;

$$\begin{aligned} &-yi + \lambda Y > 0 \\ &\theta xi - \lambda X > 0 \\ &\lambda > 0 \end{aligned} \qquad (1)$$

where, θ is the input technical efficiency score having a value $0 \leq 1$. λ is an (N x l) vector of constants while λX and λY are the input and output vectors respectively. The value of θ will be the efficiency score for the *i*-th water service operator. It will satisfy θ less than or equal to 1. Value of 1 indicates a point on the frontier and hence, a technically efficient DMU. 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. To account for variable returns to scale, the same equation can be modified with the convexity constraint ensures that an "inefficient unit" is only benchmarked against similar sized peers (DMUs). The variable returns to scale (VRS) DEA model is defined by adding the constraint (Banker, Charnes & Cooper, 1984):

$$\sum \lambda_i = 1$$

Technical efficiency score is affected by pure efficiency or scale efficiency. Pure efficiency measures the relative ability of operators to convert input into output while scale efficiency measures to what extent the operators can take advantage of return to scale by altering its size towards optimal scale (Färe, Grosskopf, Lindgren & Roos, 1994). Scale efficiency (SE) of the i-th firm can be calculated by the ratio of score technical efficiency under constant to scale with score technical efficiency under variable to scale.

$$SE_i = \frac{TE_{i\ CRS}}{TE_{i\ VRS}}$$

If SE = 1, it 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, DEAP and Efficiency Measurement System, EMS Ver. 1.3, developed by Professor Holger Scheel, University Dortmund (Scheel, 2000).

2.3 Malmquist Productivity Index

The Malmquist Productivity Index based on the DEA (Data Envelopment Analysis) was developed by the Färe et al. (1992; 1994) who merged the efficiency measurement presented by the Farrell (1957) and the measurement of productivity presented by Caves, Christensen and Diewert (1982). The Index is directly measured from input and output data by using the DEA.

The Malmquist Productivity index is used to measure the change in productivity of a firm over a time period by evaluating the ratio of distance functions in respect of a chosen technology. Let us take the two time periods, t^1 and t^2. In period t^1, a firm uses input xt^1 to produce output yt^1 and in period t^2, the same firm uses input xt^2 to produce output yt^2. Let us define the production set as technology (S) use at time t, as St = {(xt , yt): xt can produce yt}, where xt is an input vector and yt is an output vector such that $xt \epsilon$ and $yt \epsilon$ $at\ time\ t.$

Fare et al. (1994) defined an output distance function, for a firm, at time t^1 as

$$D^{t1}(x^{t1}, y^{t1}) = \inf \{\theta \epsilon R | \left(x^{t1}, \frac{y^{ti}}{\theta}\right) \epsilon S_{t1} \} \dots \dots . \qquad (2)$$

This distance function is defined as the inverse of Farrel's (1957) technical efficiency measure.

$$D^{t1}(x^{t1}, y^{t1}) = (Sup\ \theta \epsilon\ R|(x^{t1}, \theta y^{t1}) \epsilon\ S_{t1}\})^{-1} \ldots \ldots \quad (3)$$

Equation (2), gives the maximum proportional change in the outputs y^{t1} with the same inputs x^{t1}, at time t_1.

Also, $$D^{t2}(x^{t2}, y^{t2}) = \inf \{\theta \epsilon\ R|\left(x^{t2}, \frac{y^{t2}}{\theta}\right) \epsilon\ S_{t2}\} \ldots \ldots \quad (4)$$

To compute Malmquist productivity index:

$$D^{t1}(x^{t2}, y^{t2}) = \inf \{\theta \epsilon\ R|\left(x^{t2}, \frac{y^{t2}}{\theta}\right) \epsilon\ S_{t1}\} \ldots \ldots \quad (5)$$

where $D^{t1}(x^{t2}, y^{t2})$ gives the maximum proportional change in output y^{t2} with same input x^{t2} at time t^1.

And $$D^{t2}(x^{t1}, y^{t1}) = \inf \{\theta \epsilon\ R|\left(x^{t1}, \frac{y^{t1}}{\theta}\right) \epsilon\ S_{t2}\} \ldots \ldots \quad (6)$$

where $D^{t2}(x^{t1}, y^{t1})$ gives the maximum proportional change in output y^{t1} with same input x^{t1} at time t^2.

Specifically, Caves et al., (1982a, 1982b) proposed the following input-oriented productivity growth measure also known as a Malmquist index of input productivity change that can be expressed via an input distance function as:

$$M^{t1}\left(x^{t1}, y^{t1}, x^{t2} y^{t2}\right) = \frac{D^{t1}\left(x^{t1}, y^{t1}\right)}{D^{t1}\left(x^{t2}, y^{t2}\right)} \quad (7)$$

$$M^{t2}\left(x^{t1}, y^{t1}, x^{t2} y^{t2}\right) = \frac{D^{t2}\left(x^{t1}, y^{t1}\right)}{D^{t2}\left(x^{t2}, y^{t2}\right)} \quad (8)$$

D refers to the input distance function. While equation (7) gives the Malmquist input productivity change index using the period *t* technology as the reference technology, equation (8) provides the Malmquist input productivity change index using the period t^2 technology as the reference technology. Both equations compare the observed inputs in period t^1 (xt^1) and in period t^2 (xt^2) with the minimum level of inputs (keeping the input mix constant) that can produce yt^1 and yt^2 under the reference technology of period t^1 and t^2 respectively. To avoid an arbitrary choice of reference technology, Fare et al. (1992,1994) defined the Malmquist productivity index of TFP, between t^1 and t^2: $t^1 < t^2$, as the geometric mean of Mt^1 and Mt^2. 1993).

According to Färe et al. (1994a), the Malmquist TFP change index for the *i*-th production unit in line with equation (9) can be expressed as:

$$M\left(x^{t2}, y^{t2}, x^{t1}, y^{t1}\right) = \left(\frac{D^{t1}_{crs}\left(x^{t1}, y^{t1}\right)}{D^{t1}_{crs}\left(x^{t2}, y^{t2}\right)} * \frac{D^{t2}_{crs}\left(x^{t1}, y^{t1}\right)}{D^{t2}_{crs}\left(x^{t2}, y^{t2}\right)} \right)^{1/2} \quad (9)$$

where the subscript Dcrs is the input distance function under CRS (constant return to scale score). Equation (9) represents the productivity change of a unit between times t^1 and t^2 with outputs and inputs levels yt^1 xt^1 and yt^2 xt^2 respectively. A value of the Malmquist TFP index greater than unity indicates a positive TFP growth and a value less than unity means productivity decline.

Rearranging (9), Färe et al. (1992) show that the Malmquist TFP change index can be decomposed as a product of two components and can also be written as;

$$M\left(x^{t2}, y^{t2}, x^{t1}, y^{t1}\right) = \frac{D^{t1}_{crs}\left(x^{t1}, y^{t1}\right)}{D^{t2}_{crs}\left(x^{t2} y^{t2}\right)} * \left(\frac{D^{t2}_{crs}\left(x^{t1}, y^{t1}\right)}{D^{t1}_{crs}\left(x^{t1}, y^{t1}\right)} * \frac{D^{t2}_{crs}\left(x^{t2}, y^{t2}\right)}{D^{t1}_{crs}\left(x^{t2}, y^{t2}\right)} \right)^{1/2} \quad (10)$$

$$M = \text{EFFCH} * \text{TECH}$$

The first part on the right-hand side represents efficiency change, i.e. the change of the relative position of the observed production unit from the frontier between time t^1 and t^2. This usually signals the technological imitation of average practices, the change in their ability to appropriate the best existing production technology over time. In particular, a value of *EFFCH* greater than unity indicates an efficiency improvement (or catching-up), and it reflects the movement of the particular inefficient unit towards the CRS frontier; in contrast, a value less than unity is explained as the deterioration of efficiency (or falling behind). The second factor, the square root term, reflects technological change namely the shift of the frontier. Again, a value of *TECH* greater than unity means technological progress, i.e.

the expansion of the frontier, and a value less than one represents technological regress, i.e. the contraction of the frontier.

Fare et al (1994) further divided changes in the firm's technical efficiency into pure technical efficiency change (managerial efficiency) and scale efficiency change (optimal plant size) which is explained as the technical efficiency catching-up against the VRS technology frontier, and scale efficiency change, which captures movements towards the constant returns to scale portion of the estimated technology. This is represented in equation (11), where vrs (variable return to scale score) indicates VRS technology:

EFFCH

$$= \frac{D_{crs}^{t1}\left(x^{t1}, y^{t1}\right)}{D_{crs}^{t2}\left(x^{t2} y^{t2}\right)} = \frac{D_{vrs}^{t1}\left(x^{t1}, y^{t1}\right)}{D_{vrs}^{t2}\left(x^{t2}, y^{t2}\right)} * \left(\frac{D_{crs}^{t1}\left(x^{t1}, y^{t1}\right) / }{D_{crs}^{t2}\left(x^{t2}, y^{t2}\right) / } \frac{D_{vrs}^{t1}\left(x^{t1}, y^{t1}\right)}{D_{vrs}^{t2}\left(x^{t2}, y^{t2}\right)} \right) \quad (11)$$

EEFCH = PECH * SECH

Growth in productivity will occur if the $M > 1$, which means there has been a positive change in total productivity from period t^1 to period t^2. Total factor productivity change can be either due to change in efficiency or due to technical efficiency (Kaur & Aggarwal, 2016). Changes in efficiency will occur if the changes in efficiency (EFFCH) > 1, and changes in technology occur if the change in technical efficiency (TECHCH) > 1. The software used in this study is DEA Excel Solver developed by Zhu (2003).

3. Efficiency and Productivity of Malaysian Water Sector

3.1 Technical Efficiency

Based on the DEA results, the mean technical efficiency score water services is 73%. The score is determined by pure efficiency and scale efficiency. Pure efficiency refers to the ability of the industry to buy and manage input. Scale efficiency refers to the best operating results or optimal scale production.

Results also indicate the state's water operator, Pulau Pinang, is the most efficient with a score of 100% in pure efficiency and scale efficiency. Thus, allowing Pulau Pinang to achieve technical efficiency with score one over the period 2000-2013. Thus, Pulau Pinang is used as a benchmark for other state water operators. The island had been benchmarked 115 times from 2000-2013 by other state operators to adopt PBA Holding's strategies to achieve efficiency. State operators that were also benchmarked include Perak

(51 times), Perlis (31 times), Terengganu (21 times) and Kelantan (7 times) over the same period.

In terms of pure efficiency, water operators in Pahang, Malacca, Kedah, Negeri Sembilan, Kelantan were considered inefficient (refer Table 3). Pahang's water operator registered the lowest pure efficiency, 56%, followed by Malacca, 64%. This means that Pahang and Malacca should reduce their input by 44% and 36% respectively to achieve the efficiency level of Pulau Pinang. Additionally, the operators should focus on service management and recruit staff with good skills and vast experience in asset management and ensure there is minimal political interference in their management (Byrnes et al., 2010).

In terms of scale efficiency, water operators in Perlis, Perak, Selangor, Johor and Labuan were considered inefficient. Labuan registered the lowest score, 36%, followed by Johor and Selangor with 68% and 71% respectively. Labuan faces problems with the limited supply of treated water and since the population is scattered, hence, per-unit cost of water supply will be high compared with Pulau Pinang. Perlis and Perak each registered 100% score in terms of pure efficiency over the study period but their scale efficiency is less than 100% (Perlis=91% and Perak=94%). Thereby, water operators in Perlis and Perak should focus more on optimising or altering their size towards optimal scale production in order to achieve 100% scale efficiency.

Inefficiencies in the scale score are largely caused by an increase in NRW. Therefore, NRW has been used as one of the Key Performance Index by SPAN and all states has to reduce their NRW up to 26% as targeted (Diagram 1) in 2020. However, NRW rate for 2014 for all states are still above 26%, except for Pulau Pinang (18.3%), Melaka (21.4%) and Johor (25.9%) and for other states is a long way to achieve the targeted level. Thus, the most effective way in handling the NRW problems nationwide is through holistic approaches which involve the following: (i) Comprehensive leakage repair. (ii) Replacement of production meter (iii) Establishment of District Metering Zones (DMZ) (iv) Proper Water Pressure Control and (v) Replacement of dilapidated pipes. In addition, focus shall be given on complaints (Customer Service Centre) and also provision on special training to the NRW officials in making sure the holistic NRW programme could be implemented aggressively and comprehensively (Salleh & Malek, 2000).

Table 3: Overall Technical Efficiency (OTE) score in Malaysian water sector, 2000-2013

State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Kedah	0.691	0.867	0.829	0.81	0.883	0.983	0.901	0.49	0.495	0.72	0.686	0.605	0.65	0.81
Perlis	0.706	0.887	0.922	0.919	1	0.956	1	1	1	1	0.732	0.881	0.843	0.914
Pahang	0.446	0.555	0.624	0.541	0.54	0.578	0.543	0.511	0.522	0.492	0.511	0.572	0.534	0.56
N. Sembilan	1	0.9	0.903	0.525	0.59	0.822	0.885	0.743	0.815	0.468	0.486	0.583	0.627	0.623
Perak	0.69	0.785	1	1	0.881	0.941	0.937	0.951	0.916	1	1	1	1	1
Malacca	0.527	0.688	0.637	0.652	0.563	0.576	0.563	0.736	0.728	0.495	0.558	0.565	0.577	0.576
Pulau Pinang	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Terengganu	0.847	1	1	1	1	0.741	0.763	0.656	0.662	0.652	0.627	0.741	0.72	0.81
Selangor	0.872	0.857	0.794	0.792	0.804	0.839	0.645	0.589	0.652	0.654	0.623	0.71	0.561	0.585
Johor	0.759	0.777	0.74	0.713	0.668	0.531	0.579	0.72	0.678	0.633	0.504	0.48	0.494	0.504
Kelantan	0.755	0.922	0.935	0.906	0.885	1	0.915	0.81	0.747	0.719	0.724	0.779	0.802	0.87
Labuan	0.418	0.312	0.356	0.33	0.318	0.342	0.323	0.327	0.238	0.405	0.389	0.442	0.483	0.479
Purata	0.726	0.796	0.812	0.766	0.761	0.776	0.755	0.711	0.704	0.687	0.653	0.697	0.691	0.728

Table 4: Scale Efficiency Score (SE) in Malaysian water sector, 2000-2013

State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Kedah	0.9	0.867	0.977	0.998	0.888	0.983	0.928	0.986	0.972	0.999	0.994	0.993	0.99	0.997
Perlis	0.706	0.887	0.922	0.919	1	0.956	1	1	1	1	0.732	0.881	0.843	0.914
Pahang	0.991	0.852	0.992	0.992	0.89	0.982	0.967	0.963	0.933	0.979	0.966	0.983	0.979	0.994
N. Sembilan	1	0.951	0.998	0.943	0.989	0.992	0.95	0.968	0.924	0.981	0.961	0.968	0.968	0.976
Perak	0.805	0.816	1	1	0.881	0.941	0.937	0.951	0.916	1	1	1	1	1
Malacca	0.856	0.971	0.888	0.905	0.898	0.903	0.949	0.966	0.955	0.962	0.927	0.944	0.955	0.964
Pulau Pinang	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Terengganu	0.944	1	1	1	1	0.993	0.995	0.994	0.983	0.981	0.945	0.976	0.967	0.985
Selangor	0.872	0.857	0.794	0.792	0.804	0.839	0.645	0.589	0.652	0.654	0.623	0.71	0.561	0.585
Johor	0.759	0.777	0.74	0.713	0.668	0.531	0.579	0.72	0.716	0.73	0.726	0.754	0.601	0.593
Kelantan	0.918	0.982	0.972	0.971	0.929	1	0.917	0.912	0.905	0.999	0.906	0.964	0.957	0.975
Labuan	0.418	0.312	0.356	0.33	0.318	0.342	0.323	0.327	0.238	0.405	0.389	0.442	0.483	0.479
Average	**0.847**	**0.856**	**0.887**	**0.88**	**0.856**	**0.872**	**0.849**	**0.865**	**0.849**	**0.891**	**0.847**	**0.885**	**0.859**	**0.872**

Table 5: Pure Efficiency Score (PTE) in Malaysian water sector, 2000-2013

State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Kedah	0.768	1	0.849	0.811	0.994	1	0.97	0.497	0.51	0.722	0.69	0.609	0.656	0.812
Perlis	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pahang	0.45	0.652	0.628	0.545	0.606	0.589	0.562	0.53	0.56	0.503	0.529	0.581	0.545	0.564
N. Sembilan	1	0.946	0.906	0.557	0.596	0.828	0.931	0.768	0.882	0.477	0.506	0.602	0.648	0.638
Perak	0.858	0.961	1	1	1	1	1	1	1	1	1	1	1	1
Malacca	0.615	0.709	0.717	0.721	0.627	0.638	0.594	0.761	0.762	0.514	0.602	0.599	0.605	0.597
Pulau Pinang	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Terengganu	0.897	1	1	1	1	0.747	0.767	0.66	0.674	0.665	0.664	0.759	0.745	0.822
Selangor	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Johor	1	1	1	1	1	1	1	1	0.947	0.867	0.694	0.637	0.823	0.85
Kelantan	0.822	0.94	0.962	0.933	0.953	1	0.997	0.888	0.825	0.72	0.798	0.808	0.839	0.892
Labuan	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Average	**0.868**	**0.934**	**0.922**	**0.881**	**0.898**	**0.9**	**0.902**	**0.842**	**0.847**	**0.789**	**0.79**	**0.8**	**0.822**	**0.848**

Figure 1: Percentage of NRW in 2014 and target for 2020

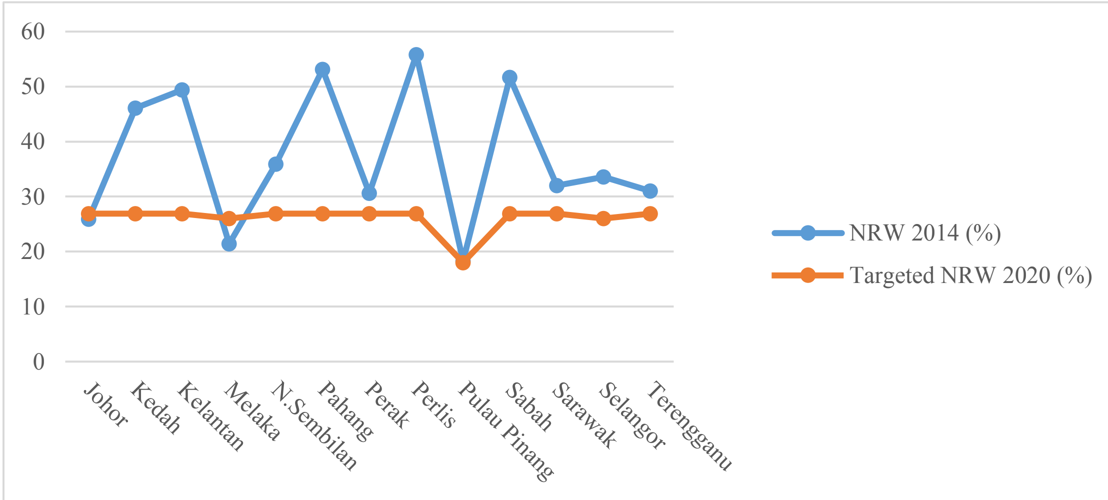

Table 6: Return to scale for Malaysian water service from 2000-2013

	Before restructuring									After restructuring				
Scale	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
CRS	2	2	3	3	3	2	2	2	2	3	2	2	2	2
IRS	5	4	5	6	2	4	3	2	1	6	8	8	8	8
DRS	5	6	4	3	7	6	7	8	9	3	2	2	2	2

States such as Penang, Johor, Selangor, Kelantan and Terengganu which had privatised their water supply, showed average efficiency score between 50% and 80%. However, average efficiency score of state managed ones such as Perlis is 90%. This means that the efficiency of the water supply operator is not determined by the type of ownership. This is consistent with Feigenbaum and Teeples (1983), Byrnes, Grosskopf and Hayes (1986) and Teeples and Gyler (1987) who showed that the type of ownership is not the main factor in determining the efficiency of the operators; instead, human resources and assets are the main factors that contribute to the efficiency in water supply.

Based on the technical efficiency scores, the establishment of SPAN has had a positive impact on the efficiency of water supply operators. Almost all states displayed improvement in their technical efficiency score except for Selangor and Johor which means the latter should reach their optimal level by using all the infrastructure that they have. In addition, both are states which are dependent on manufacturing and agricultural industries with high demand for water in addition to being densely populated. Therefore, the demand for treated water is increasing at a fast pace and hence, long-term planning should be made to ensure adequate water supply to meet the demand. Selangor has 5 main rivers that supply water but they cannot cope with future demand. Additionally, water treatment plants take a long time to be completed (KeTHA, 2017).

Table 6 shows that Pulau Pinang can maintain its CRS for 14 years. Perlis and Terengganu had a score of one pre restructuring and after restructuring (2008), Pulau Pinang and Perak emerged as two states that can maintain their score (one) between 2010 and 2013. Almost 67% of the states showed increasing return to scale after restructuring starting from 2010 until 2013, but their overall efficiency is still below one, considered inefficient. Thus, with the establishment of SPAN, these states can maintain their increasing return to scale while in 2010, only Johor and Selangor showed decreased return to scale. These two states showed decreasing return to scale for 14 years from 2000-2013

Selangor has a declining trend in its efficiency growth due to the decrease in its scale of growth by -3.5%. This is due to the river sources drying up and water levels falling to critical levels in seven of the state's dams, including as low as 31% of capacity at the Sungai Selangor Dam, which supplies more than 60% of the state's water. The shortage of potable water supply is not entirely due to inadequate capacity of Water Treatment Plants (WTPs) and distribution infrastructure. It is mainly as a result of inadequate water resources recharge, environmental pollution exacerbated by low flows of river water sources by industries and poorly operated sewerage treatment plants as well as indiscriminate waste disposal by the public that consequently forced shutdowns of WTPs. Besides that, Selangor NRW was increased from 32.49% in 2010 to 33.6% in 2014 as a result of pipes laid over 50 years ago. Therefore, a huge sum of money is needed to replace about 6000 km of pipes. Assuming per meter cost of standard sized (300mm) steel pipes is RM500, the estimated replacement value is RM3 billion which is very costly for the state. Negeri Sembilan also faced the similar problems caused by prolonged drought which affected its seven dams, water infrastructure problems and political deadlock in negotiations between the government and private water concessionaires.

In Johor, drought as a result of the El Nino phenomenon, led to a drastic drop in water level at its dam - between 2.5m and 2.6m - which is dangerously below the critical level of 3.5m. The drought affected the output at the Tenglu water treatment plant, which relies on raw water sourced from the Congok Dam. The dam relies solely on rainwater to replenish its reserves. As a result, 40,000 people in Mersing, 600,000 people in Pasir Gudang, Masai and parts of Johor Bahru as well as another 66,000 people in Tanjung Surat, Pantai Timur and parts of Kota Tinggi had also experienced water rationing around the same time due to the low water levels recorded at two dams in the state in 2016. Johor's water woes are aggravated by an increasing demand for treated water from industrial areas in Pengerang where there is a mammoth Refinery and Petrochemicals Integrated Development (Rapid) project at Pasir Gudang, as well as the Iskandar Malaysia development zone and demands from Singapore. The state Public Works, Rural and Regional Development Committee chairman Datuk Hasni Mohammad, said the state was seriously looking at other sources of water since the launch of a new project called Forest City which is a 1,386ha with mixed development project. It includes a smart city on man-made islands along the Johor Strait that will increase the demand for water in Johor (Sim & Benjamin, 2016).

Table 8: Technical Efficiency Change Score (TECHCH) for year *t and t+1 (*2000-2013), for state water operator

State	Kedah	Perlis	Pahang	N. Sem.	Perak	Malacca	P. Pinang	Trg.	Selangor	Johor	Kelantan	Labuan	Average
2000-2001	0.875	0.821	0.871	0.854	0.955	0.872	0.916	0.884	1.204	1.208	0.949	1.034	0.946
2001-2002	0.939	0.878	0.863	0.949	1.089	1.016	1.013	0.875	1.021	1.024	0.895	1.021	0.963
2002-2003	1.119	1.059	1.089	1.054	1.03	1.014	1.028	1.592	1.062	1.013	1.046	1.018	1.085
2003-2004	0.88	0.988	0.925	0.873	0.845	0.973	0.998	0.611	1.013	0.986	0.976	1.018	0.916
2004-2005	0.884	0.84	0.866	0.92	0.918	1.007	0.982	0.883	1.008	1.002	0.842	1.01	0.928
2005-2006	1.007	1.033	1.007	0.999	0.996	0.996	0.992	0.992	1.007	0.981	1.027	1.007	1.004
2006-2007	1.201	1.341	1.204	1.21	1.208	1.2	1.103	1.21	1.114	1.191	1.264	1.033	1.187
2007-2008	1.421	1.667	1.525	1.345	1.4	1.528	1.612	1.646	1.576	1.382	1.44	1.444	1.495
2008-2009	0.988	0.878	1.027	1.057	1.082	1.021	0.987	0.947	0.966	1.059	1.038	0.987	1.002
2009-2010	1.017	0.964	1.002	0.988	0.997	0.99	1.015	1.023	1.023	0.988	0.971	1.042	1.002
2010-2011	0.922	0.936	0.909	0.943	0.945	0.922	0.927	0.892	0.85	0.919	0.936	0.974	0.923
2011-2012	0.956	0.909	0.944	0.952	0.928	0.958	0.985	0.933	0.983	0.964	0.909	1.009	0.952
2012-2013	0.926	0.896	0.929	0.944	0.914	0.951	0.98	0.94	0.988	0.963	0.892	0.988	0.942
Average	1.01	1.016	1.012	1.007	1.024	1.034	1.041	1.033	1.063	1.052	1.014	1.045	1.027

Table 9: Efficiency Change Score (EFFCH) for year *t* and *t+1* (2000-2013), for state water operator

State	Kedah	Perlis	Pahang	N. Sem.	Perak	Malacca	P. Pinang	Trg.	Selangor	Johor	Kelantan	Labuan	Average
2000-2001	1.234	1.256	1.241	0.858	1.015	1.269	1	1.181	0.838	1.318	1.325	0.744	1.087
2001-2002	0.956	1.039	1.123	1.004	1.274	0.925	1	1	0.926	0.952	1.013	1.14	1.025
2002-2003	0.977	0.997	0.867	0.581	1	1.025	1	1	0.997	0.963	0.969	0.926	0.933
2003-2004	1.09	1.088	0.998	1.124	0.881	0.863	1	1	1.016	0.937	0.977	0.965	0.992
2004-2005	1.114	0.956	1.071	1.394	1.068	1.022	1	0.741	1.044	0.794	1.129	1.074	1.022
2005-2006	0.916	1.046	0.94	1.077	0.996	0.978	1	1.029	0.769	1.091	0.915	0.944	0.971
2006-2007	0.544	1	0.94	0.84	1.015	1.306	1	0.86	0.914	1.243	0.886	1.014	0.944
2007-2008	1.01	1	1.022	1.096	0.963	0.99	1	1.009	1.107	0.941	0.921	0.727	0.977
2008-2009	1.455	1	0.943	0.574	1.092	0.679	1	0.985	1.004	0.934	0.963	1.703	0.99
2009-2010	0.952	0.732	1.039	1.038	1	1.129	1	0.961	0.952	0.796	1.006	0.96	0.958
2010-2011	0.882	1.204	1.118	1.199	1	1.012	1	1.182	1.14	0.954	1.077	1.138	1.071
2011-2012	1.073	0.957	0.934	1.076	1	1.022	1	0.972	0.79	1.029	1.03	1.091	0.995
2012-2013	1.246	1.085	1.049	0.993	1	0.998	1	1.125	1.042	1.019	1.084	0.992	1.051
Average	1.035	1.028	1.022	0.989	1.023	1.017	1.000	1.003	0.965	0.998	1.023	1.032	1.001

Table 10: Pure Efficiency Change Score (PECH) for year *t* and *t+1* (2000-2013), for state water operator

State	Kedah	Perlis	Pahang	N. Sem.	Perak	Malacca	P. Pinang	Trg.	Selangor	Johor	Kelantan	Labuan	Average
2000-2001	1.302	1	1.449	0.946	1.12	1.12	1	1.115	1	1	1.216	1	1.097
2001-2002	0.849	1	0.964	0.957	1.04	1.011	1	1	1	1	1.024	1	0.986
2002-2003	0.956	1	0.867	0.615	1	1.005	1	1	1	1	0.97	1	0.943
2003-2004	1.225	1	1.112	1.07	1	0.87	1	1	1	1	1.022	1	1.022
2004-2005	1.006	1	0.971	1.39	1	1.018	1	0.747	1	1	1.05	1	1.007
2005-2006	0.97	1	0.955	1.124	1	0.93	1	1.027	1	1	0.997	1	0.999
2006-2007	0.513	1	0.943	0.825	1	1.282	1	0.861	1	1	0.89	1	0.925
2007-2008	1.025	1	1.055	1.148	1	1.002	1	1.02	1	0.947	0.928	1	1.009
2008-2009	1.416	1	0.899	0.541	1	0.674	1	0.987	1	0.916	0.873	1	0.92
2009-2010	0.956	1	1.052	1.06	1	1.172	1	0.998	1	0.8	1.11	1	1.009
2010-2011	0.883	1	1.099	1.19	1	0.994	1	1.144	1	0.918	1.013	1	1.017
2011-2012	1.076	1	0.938	1.076	1	1.01	1	0.982	1	1.291	1.037	1	1.031
2012-2013	1.238	1	1.034	0.985	1	0.988	1	1.104	1	1.033	1.064	1	1.035
Average	1.032	1.000	1.026	0.994	1.012	1.006	1.000	0.999	1.000	0.993	1.015	1.000	1.000

Table 11: Scale Efficiency Change Score (SECH) for year *t* and *t+1* (2000-2013), for state water operator.

State	Kedah	Perlis	Pahang	N. Sem.	Perak	Malacca	P. Pinang	Trg.	Selangor	Johor	Kelantan	Labuan	Average
2000-2001	0.947	1.256	0.857	0.906	0.906	1.134	1	1.06	0.838	1.318	1.09	0.744	0.991
2001-2002	1.126	1.039	1.165	1.049	1.225	0.915	1	1	0.926	0.952	0.99	1.14	1.04
2002-2003	1.022	0.997	1	0.945	1	1.02	1	1	0.997	0.963	0.999	0.926	0.989
2003-2004	0.89	1.088	0.897	1.05	0.881	0.992	1	1	1.016	0.937	0.957	0.965	0.971
2004-2005	1.107	0.956	1.103	1.003	1.068	1.005	1	0.993	1.044	0.794	1.076	1.074	1.015
2005-2006	0.944	1.046	0.984	0.958	0.996	1.051	1	1.003	0.769	1.091	0.917	0.944	0.972
2006-2007	1.062	1	0.996	1.018	1.015	1.018	1	0.999	0.914	1.243	0.994	1.014	1.02
2007-2008	0.986	1	0.969	0.955	0.963	0.988	1	0.988	1.107	0.994	0.992	0.727	0.968
2008-2009	1.028	1	1.049	1.062	1.092	1.008	1	0.998	1.004	1.019	1.104	1.703	1.076
2009-2010	0.996	0.732	0.987	0.979	1	0.963	1	0.963	0.952	0.995	0.907	0.96	0.95
2010-2011	0.999	1.204	1.017	1.007	1	1.018	1	1.034	1.14	1.039	1.064	1.138	1.053
2011-2012	0.997	0.957	0.996	1	1	1.012	1	0.99	0.79	0.797	0.992	1.091	0.965
2012-2013	1.007	1.085	1.015	1.008	1	1.01	1	1.019	1.042	0.987	1.019	0.992	1.015
Average	1.009	1.028	1.003	0.995	1.011	1.010	1.000	1.004	0.965	1.010	1.008	1.032	1.002

3.2 Total Factor Productivity Score (Malmquist Index)

Total Factor Productivity (TFP) is a combination of technical efficiency change (EEFCH) and technological change (TECH). Therefore, efficiency gains (losses) or technological progress (retardation) or both can cause an increase in productivity. Due to technologically superior equipment, pump, pipe as well as innovation in water technology. Increase in efficiency entails the use of best techniques in management and administration of water supply.

The result from Malmquist Index shows Malaysian water industry productivity growth in average was 2.4% during the period from 2000-2013. The increase was noted before the restructuring of water services, between 2000 and 2007. After 2008 almost all state showed a decline in total factor productivity. Increase in productivity is also affected by increase in budgetary allocation by the federal government under 10th Malaysian Plan which is about RM8 billion. During the period between 2008 and2009 almost all states showed a decline in productivity, and this trend continued until 2013. Between 2010-2011only a few states showed improvement in productivity such as Perlis (12%), Negeri Sembilan (13%)Terengganu (5.5%), Kelantan 8% and Labuan 10%. Only Kedah, Terengganu and Selangor showed positive productivity between 2012-2013, 15%, 5.7% and 3% respectively. The increase comes from change in pure efficiency change and none of the state showed that their productivity increased due to technological changes except for Labuan with technical change score 1.009 means that there are 9% improvement in technology during 2011-2012.

Thus, before transition, technological efficiency appears to be the major contributor to TFP growth but after restructuring, productivity growth was led by pure efficiency change. Results showed that all the states used available technology to operate even though they have moved to the "asset light model" under Water Asset Management Company (WAMCO). The states that have move toward asset light model under PAAB are Melaka (2008), Negeri Sembilan (2009), Johor (2009), Perlis (2010), Pulau Pinang (2011), Perak (2012) and Kelantan (2016), while for other states, the negotiations are on-going.

4. Conclusion

This study has shown that the establishment of SPAN and PAAB has had a small but positive impact on the efficiency of state-owned water operators. This is based on the result of technical efficiency in Penang (scale 1 in 2000-2008) and which has maintained its efficiency score of 1 over the period 2009-2013, despite the restructuring of the water supply industry. The island's water operator, PBA Holdings has made significant improvements in water supply management and services through the privatisation programme since the early 1990s (Chan, 2007). It has achieved ISO9000 Quality Standards and also maintained ISO14001 standards for environmental quality. Additionally, PBAPP has contributed towards water conservation by working closely with NGOs, especially Water Watch Penang (WWP), in its conservation programmes. It is also committed to sharing its profits with its employees and the public via share offers on the stock exchange. However, the water operator in Perlis (Syarikat Air Perlis), it efficiency fell from a scale of 1 to 0.732 (2008-2010) though it showed improvement in terms of efficiency after 2010. The fall in efficiency scored was initially attributed to the restructuring period following the corporatisation of the water operator in 2009-2010. The restructuring is in line with the policy SPAN-PAAB, and thus, the increased the level of efficiency of the water operator from 2010 to 2013. It can be said that the establishment of SPAN-PAAB and its policies has improved the efficiency of state's water operators despite the fact the SPAN-PAAB partnership is less than 5 years (2008-2013). In the long run, SPAN -PAAB will have a positive and significant impact on the efficiency of the state's water operator

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