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Productivity Change of Water Districts in Region 12 using Data EnvelopmentAnalysis Based Malmquist Productivity Index

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ABSTRACT: Benchmarking tools have gained interest in recent years to assess the effectiveness of reforms and performance of water companies. This study aimed to estimate the productivity change of water districts in region 12 using the Data Envelopment based Malmquist Productivity Index from 2014 to 2018. It was found out that the sources of productivity were technological changes for the majority of the water districts. Water districts have increased capital investment to improve technology. Subsequently, inefficient water districts may adopt the peer weights of referenced decision-making units to adjust inputs to attain productivity. Moreover, having a centralized policy covering the set standards and policies of the concerned agencies is necessary for the water districts to develop good water governance.

Keywords: *DEA-based Malmquist Productivity Index, efficiency change, technological change, management efficiency, scale efficiency.*

I. INTRODUCTION

Many water service providers characterized the Philippine water supply sector. The agricultural industry consumes most of the water resources in the country, followed by the industrial sectors, and the remainder goes to home users GREENPEACE, 2007). Hence, there are still issues with the management of water systems of water districts (Abrilla and Yee, 2016), such as water quality and accessibility, water shortages, and temporal distribution (Abrilla and Yee, 2016; Rubio, Lee, and Jeong, 2008) despite the availability of water in the Philippines.

The three primary processes in the drinking water supply are the abstraction of raw water resources and raw water treatment, the transmission of drinking water, and the distribution of drinking water to final consumers (Zschille, 2014). The productive outcome is a primary concern of water districts. However, there have been problematic issues such as aging infrastructure, financing improvements and organizational competence, integrating innovative technologies or technical operations, and human resource management faced by water districts in Region 12 (USAID, n.d.). Additionally, inefficiencies associated with water restriction regimes, flaws in supply and demand planning, and investment processes may result in rising and continual issues for the water sector, particularly deteriorating transportation system and water quality threats (Worthington, 2015).

The Malmquist productivity index techniques have gained popularity in assessing the productivity of water companies (Carvalho & Marques, 2014). A growing number of studies evaluating the performance of water utilities around the world have attempted to quantify and measure water utility productivity. These studies highlighted management deficiencies, realized and quantified effects of regulatory and structural factors, identified and quantified constraints to productive results in the sector, and provided measurable inputs into the future improvement of the process by measuring the productivity of water sectors (Maziotis, Senante and Garrido, 2016).

The Malmquist productivity index compares the productivity of DMUs or a single DMU over different periods. The technical efficiency and technological change are decomposed in the Malmquist productivity index (Uddin, 2015). These evaluate managerial competence of water districts to respond to variations in scale efficiency, capability to change factor inputs, long-term strategic planning quickly, and timely capital investment to address the issues concerning productivity change of water districts in Region 12 (Simoes and Marques, 2012; Senante, Maziotis and Garrido, 2014).The effectiveness and intensity of delivering successful results for the organization are entirely based on the organizations' purely technical, technical, and technological efficiency (Afonso, Ayadi, & Ramzi, 2013).

There appears to be no current study employing the DEA-based Malmquist Index to examine the productivity of water districts in Region 12. The goals of measuring the productivity of water districts are to identify the essential sources of productivity gains, such as efficiency and technological improvements enable to determine the number of inputs required to be reduced and improve the quality of outputs produced and alterations in the operating conditions.

The overall aim of the study was to determine the productivity change of water districts in Region 12 from 2014 to 2018 using Data Envelopment Analysis based Malmquist Productivity Index. This research is significant for global, national, and municipal water utility policymakers and service provider managers. The findings may provide knowledge that may be utilized as a benchmarking tool, particularly in production and resource development.

II. METHODS

The study focuses on estimation or productivity of water districts in Region 12 using DEA Based Malmquist productivity index. The study was designed using exploratory research. The study was carried out in Region 12, Philippines.The data set includes observations from a panel of 12 water districts in Region 12 from 2014 to 2018. The data comes primarily from LWUA reports on water rates and annual audit reports, focusing on the financial component. The data was gathered with the permission of the water district institutions and was kept confidential.

Table 1. *Data Specifications of Factors Inputs and Outputs*

Factor Inputs	Factor Outputs
Length of mains	Connection properties
Maintenance and other operating expenses	Volume of water delivered
Personal services	

Estimation Procedure

The statistical tool that this study was utilized is DEA based Malmquist productivity index (input distance function). The productivity difference between the DMUs or a DMU over the two periods of time was analyzed using Malmquist Index (Uddin, 2015).

The researcher used DEAP 2.1 program developed by Coelli (1996b) to measure the productivity indexes. The researcher applied Constant Return to Scale input-oriented to evaluate the efficiency change over time, the Malmquist productivity index issued in the following analysis:

Suppose each DMU_j (j = 1, 2, …n) produces a vector of outputs Y^t_j (Y^t_{1j}, …… Y^t_{sj}) by using a vector inputs X_j (X^t_{1j}, …… X^t_{sj}) at each period t, t = 1, 2, …T. When multiple inputs are used to produce multiple outputs, distance functions provide a functional characterization of the structure of production technology. The output distance function is defined on the output set, P(x) (Shepard, 1953, Nourali, Davoobadi, and Pashazade, 2014);

$$D_o(x, y) = \max \{(\partial : y / \partial \ E \ P(x)\}$$

The output-based Malmquist productivity index between the period t and t+1 is the output-based productivity change index may be formulated as (Caves, Christensen & Diewert (1982, Sufian, 2007) :

$$MPI_o^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{D^t_{jCRS}(y^{t+1}, x^{t+1})}{D^t_{jCRS}(y^t, x^t)} x \frac{D^{t+1}_{jCRS}(y^{t+1}, x^{t+1})}{D^{t+1}_{jCRS}(y^t, x^t)}\right]^{1/2} \quad (1)$$

Where,

MPI = Malmquist productivity index between the two periods.

t, t+1= The superscripts describe the periods

0 = the subscript denotes the orientation

D = the distance function

By rearranging the equation, Färe and Primton (1995) proposed the Malmquist productivity index as a product of efficiency change and technical change as an equation;

$$M_j^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{D_{jCRS}^{t+1}(y^{t+1}, x^{t+1})}{D_{jCRS}^{t}(y^{t}, x^{t})} x \left[\frac{D_{jCRS}^{t}(y^{t+1}, x^{t+1})}{D_{jCRS}^{t+1}(y^{t+1}, x^{t+1})} x \frac{D_{jCRS}^{t}(y^{t}, x^{t})}{D_{jCRS}^{t+1}(y^{t}, x^{t})}\right]^{1/2} \quad (2)$$

or MPI = effch x techch

The first term before the square root is the ratio of the two distance functions measures Farrell (1957, Uddin, 2015) technical efficiency change (effch) from the period t to the period (t+1). The second term measures technological progress (techch) from period t to the period (t+1).

Malmquist productivity index of the firm is greater than 1 (MPI>1), indicative of productivity growth gains. The sources and their magnitude to the Malmquist productivity index reflect from efficiency change (effect) ratio and technical progress (techch) ratio.

Where:

Technical Efficiency (effch) = $\frac{D_{jCRS}^{t+1}(y^{t+1}, x^{t+1})}{D_{jCRS}^{t}(y^{t}, x^{t})}$ (3)

Technological Change (techch) = $\left[\frac{D_{jCRS}^{t}(y^{t+1}, x^{t+1})}{D_{jCRS}^{t+1}(y^{t+1}, x^{t+1})} x \frac{D_{jCRS}^{t}(y^{t}, x^{t})}{D_{jCRS}^{t+1}(y^{t}, x^{t})}\right]^{1/2}$ (4)

As one can note, the decomposition of Malmquist index of Färe et al. (1992) does not consider the variable returns to scale (VRS) technology and, consequently, scale efficiency. The input-oriented geometric mean of MPI is decomposed using the concept of input-oriented technical change(TECHCH) and input-oriented efficiency change(EFFCH) as given in equation (5).Thus, the Malmquist (MPI) productivity index was decomposed into three parts:

MPI = effch * techch = pech * sech * techch

Pure Technical Efficiency Change (pech) = $\frac{D_{jVRS}^{t+1}(y^{t+1}, x^{t+1})}{D_{jVRS}^{t}(y^{t}, x^{t})}$ (5)

Scale Efficiency (sech) = $\left[\frac{\frac{D_{jCRS}^{t+1}(y^{t+1}, x^{t+1})}{D_{jVRS}^{t+1}(y^{t+1}, x^{t+1})}}{\frac{D_{jCRS}^{t}(y^{t}, x^{t})}{D_{jVRS}^{t}(y^{t}, x^{t})}}\right]$ (6)

Thus, pure technical efficiency and scale efficiency change measure firm-specific changes in productivity related to shifts in technical and scale efficiency, whereas technological changes identify shifts in the technology frontier.

III. RESULTS

Table 2 shows the descriptive statistics of factor inputs and outputs of water districts in region 12 from 2014 to 2018. The result found out that water districts' factor inputs and outputs have increased from 2014 to 2018. Specifically, the increasing volume of water delivered and connection properties are due to increasing household demand with access to safe drinking water. To do so, the water districts increased the maintenance and other operating expenses, personnel services, and length of mains for over five years. The volume of water delivered and personal services, in particular, had the most fluctuation across the outputs and inputs.

Table 2. *Descriptive Statistics of Factor Inputs and Outputs of Water Districts from 2014 to 2018*

	Output	Inputs

Year		Volume of water Delivered	Connection properties	MOOE	Personnel Services	Length of mains
2014	Std. Dev.	4191745	10941	22416001	26395306	13695
	Average	2010539	6343	13109919	13991685	16498
2015	Std. Dev.	4907388	11306	24515310	31377209	16680
	Average	2316379	6712	15353572	16463939	21070
2016	Std. Dev.	5635527	12055	29360882	38244316	18641
	Average	2631684	7233	17882093	19370163	23252
2017	Std. Dev.	5971725	12751	33069379	42687127	19202
	Average	2825313	7789	20123488	21425083	24656
2018	Std. Dev.	6498019	13505	35357645	47514503	19352
	Average	3073448	8398	21635167	23716658	24942

Table 3 shows the productivity elements of water districts in the year 2014-2015. The result found that DMUs 2, 6, 7, and 9 were productive in 2014-2015. Adversely, DMU 4 was observed technically inefficient. Thus, there is a need for DMU 4 to increase or decrease MOOE, length of mains, and personnel services by 15.3% to upsurge water delivered, and connection properties enable to attain efficiency. Also, DMU 4 observed inefficient variable returns to scale and thereby needed to increase or decrease inputs by 1.2% to become efficient. In terms of technological change, only DMUs 6 and 9 were efficient. Some of the DMUs were needed to increase MOOE, length of mains, and personnel services by 7.4% (DMU 1), 9% (DMU 2), 9.22% (DMU 3), 10.7% (DMU 4), 2.1% (DMU 5), 9.4% (DMU 7), 7.3%(DMU 8), 26.3%(DMU 10), 13% (DMU 11), and 56.8% (DMU 12) to become efficient. This implies that efficient water districts considerably increase investment to improve technological advancement.

Table 3.*Productivity Elements forthe Water Districts in Region 12, 2014-2015*

DMUs	Technical Efficiency Changes	Technological Changes	Management Efficiency	Scale Efficiency	Productivity Change
1	1.000	0.926	1.000	1.000	0.926
2	1.141	0.910	1.123	1.016	1.039
3	1.000	0.908	1.000	1.000	0.908
4	0.837	0.893	0.847	0.988	0.747
5	1.000	0.979	1.000	1.000	0.979
6	1.002	1.003	1.000	1.002	1.005
7	1.189	0.906	1.000	1.189	1.077
8	1.049	0.927	1.000	1.049	0.972
9	1.000	1.241	1.000	1.000	1.241
10	1.000	0.737	1.000	1.000	0.737
11	1.113	0.870	1.000	1.095	0.969
12	1.000	0.432	1.017	1.000	0.432
Mean	**1.024**	**0.872**	**0.997**	**1.027**	**0.893**

Table 4 shows the productivity elements of water districts in the years 2015-2016. The productivity of DMUs 7, 8, and 9 increased from 2015 to 2016. They boosted productivity by 7%, 5.5%, and 12.1%, respectively. This implies that DMUs 7, 8, and 9 attain maximum scale production, and at the same time, resources were utilized correctly. This also means that technological advancement is considerably improved. DMUs 1, 2, 3, 4, 5, 6, 10, 11, and 12, on the other hand, were inefficient. To become technically efficient, DMUs 2, 4, and 6 needed to improve connection properties and volume of water delivered by increasing or decreasing MOOE, length of mains, and personnel services by 6.9%, 3.5%, and 5.5%, accordingly. Additionally, DMUs 2, 4, and 11 need to utilize inputs properly to efficiently produce a volume of water delivered and connection properties. More so, DMUs 2 and 6 have obtained variable returns to scale inefficiency and so increasing or decreasing returns by 2.2% and 4.6%, respectively. In terms of technological change, DMUs 1, 3, 4, 5, 10, and 11 were inefficient and needed to increase MOOE, length of mains, and personnel services by 3%, 2.8%, 4.1%, 9.7%, 15.4%, and 7.2% accordingly. It implies that innovation and technology have a vital role in producing water districts.

Table 4. *Productivity Elements for the Water Districts in Region 12, 2015-2016*

DMUs	Technical Efficiency Changes	Technological Changes	Management Efficiency	Scale Efficiency	Productivity Change
1	1.000	0.970	1.000	1.000	0.970
2	0.931	1.006	0.953	0.978	0.937
3	1.000	0.972	1.000	1.000	0.972
4	0.965	0.959	0.962	1.004	0.926
5	1.000	0.926	1.000	1.000	0.926
6	0.945	1.034	1.000	0.954	0.977
7	1.000	1.007	1.000	1.000	1.007
8	1.040	1.015	1.000	1.040	1.055
9	1.000	1.121	1.000	1.000	1.121
10	1.000	0.846	1.000	1.000	0.846
11	1.040	0.928	0.976	1.045	0.947
12	1.000	1.215	1.000	1.000	8.215
Mean	**0.991**	**1.168**	**0.991**	**1.001**	**1.158**

Table 5 shows the productivity elements of water districts in 2016-2017. Water districts 3, 5, 7, 8, and 10 were productive in 2016-2017. These water districts upsurge productivity changes by 5.1%, 5%, 0.8%, 31.1% and 3.6% respectively. This implies that these DMUs were efficiently operating using the available resources (MOOE, length of mains, and personnel services) to improve technological advancement to upswing water delivered and connection properties. More specifically, in technical efficiency change, DMUs 2, 6, and 11 were observed inefficient. Hence, they need to increase or decrease by 8.8%, 9.7%, and 15.2% of MOOE, length of mains, and personnel services to improve the supply system of water delivered and connection properties. Also, DMUs 7 and 11 were observed inefficient returns of scale and thereby needed to increase or reduce inputs by 1.8% and 10.4% accordingly to achieve desired water delivered and connection properties. DMUs 2, 6, and 11 were inefficient for a technological change. On this account, there is a need to increase inputs from operations by 6.2%, 2.2%, and 85.1%. This could mean that inadequate investment shall take into consideration.

Table 5. *Productivity Elements for the Water Districts in Region 12, 2016-2017*

DMUs	Technical Efficiency Changes	Technological Changes	Management Efficiency	Scale Efficiency	Productivity Change
1	1.000	0.997	1.000	1.000	0.997
2	0.912	0.992	0.938	1.031	0.905
3	1.000	1.051	1.000	1.000	1.051
4	1.040	0.940	1.059	1.026	0.977
5	1.000	1.050	1.000	1.000	1.050
6	0.913	1.018	0.978	1.122	0.929
7	1.000	1.008	1.000	0.982	1.008
8	1.027	1.276	1.000	1.027	1.311

9	1.000	0.926	1.000	1.000	0.926
10	1.000	1.036	1.000	1.000	1.036
11	0.848	1.001	0.849	0.896	0.849
12	1.000	0.134	1.000	1.000	0.134
Mean	**0.977**	**0.864**	**0.984**	**0.993**	**0.844**

Table 6 shows the productivity elements of water districts in the years 2017-2018. DMUs 1, 2, 4, 5, 9, 10, and 12 were productive in 2017-2018. These DMUs improved by 43.3%, 8.5%, 26.7%, 22.5%, 13.1%, 5.4%, and 18.5%, denoting that these DMUs are operating efficiently at their maximum scale capacity and improved technological advancement and innovation. For more distinctive efficiency changes, DMUs 6, 7, and 8 were inefficient. Hence, to become technically efficient, they needed to increase or decrease the MOOE, length of mains, and personnel services by 3.6%, 1.8%, and 10.7%, respectively. In terms of management efficiency, DMUs 6 and 8 were noticeably inefficient. Henceforth, there is a need to improve production by increasing or decreasing inputs by 14.1% and 5.4%. For a technological change, DMUs 7, 8, and 11 were observed decreasing returns to scale. Thus, there is a need to increase inputs of water districts by 1.8%, 5.6%, and 10.4% in operation to constant or increase returns of scale. In addition, DMUs 3, 7, 8, and 11 were recognized as inefficient. On this account, these DMUs need to increase inputs by 5.3%, 1.9%, 25.6%, and 10.5%. Hence, a deterioration in technological progress, a slight decline in management, and scale efficiency were observed. The limit in investment, scale activity, and improper utilization of productive resources can drag down productivity. There was a slight decrease in scale efficiency on the average productivity index of water districts.

Table 6. *Productivity Elements for the Water Districts in Region 12, 2017-2018*

DMUs	Technical Efficiency Changes	Technological Changes	Management Efficiency	Scale Efficiency	Productivity Change
1	1.000	1.433	1.000	1.000	1.433
2	1.077	1.007	1.044	1.031	1.085
3	1.000	0.947	1.000	1.000	0.947
4	1.190	1.065	1.159	1.026	1.267
5	1.000	1.225	1.000	1.000	1.225
6	0.964	1.029	0.859	1.122	0.992
7	0.982	0.981	1.000	0.982	0.963
8	0.893	0.744	0.946	0.944	0.664
9	1.000	1.131	1.000	1.000	1.131
10	1.000	1.054	1.000	1.000	1.054
11	1.108	0.895	1.237	0.896	0.992
12	1.000	1.185	1.000	1.000	1.185
Mean	**1.015**	**1.054**	**1.016**	**0.999**	**1.061**

Table 7 shows the productivity elements (summary of firm means) of water districts in the years 2014-2018. DMUs 1, 5, 7, and 9 were productive for five years from 2014 to 2018. These DMUs improved production by 6.4%, 3.9%, 1.2%, and 9.9%. However, DMU 6 is technically inefficient (0.956). This means that there is a need to increase or decrease inputs (length of mains, personnel services, and MOOE) by 4.3% to improve the volume of water delivered and connection properties. Also, to attain optimal production, there is a need to increase such inputs by 1.2%. In terms of technological improvement, water districts 2, 3, 4, 7, 8, 10, 11 and 12 were thereby needed to raise average inputs by 2.2%, 3.2%, 3.8%, 2.6%, 2.8%, 9.2%, 7.8% and 13.4% to improve technological advancement and innovation.

Table 7. *Summary of Firm Means of Water Districts in Region 12, 2014-2018*

DMUs	Technical Efficiency Changes	Technological Changes	Management Efficiency	Scale Efficiency	Productivity Change
1	1.000	1.064	1.000	1.000	1.064
2	1.011	0.978	1.012	0.999	0.989
3	1.000	0.968	1.000	1.000	0.968
4	1.000	0.962	1.000	1.000	0.962
5	1.000	1.039	1.000	1.000	1.039
6	0.956	1.021	0.957	0.998	0.976
7	1.039	0.974	1.000	1.039	1.012
8	1.000	0.972	0.986	1.014	0.972
9	1.000	1.099	1.000	1.000	1.099
10	1.000	0.908	1.000	1.000	0.908
11	1.016	0.922	1.010	1.006	0.937
12	1.000	0.866	1.000	1.000	0.866
Mean	**1.022**	**0.979**	**0.997**	**1.005**	**0.981**

IV. DISCUSSION

The connection properties and volume of water to be delivered are the outputs considered in the study. Increasing finances for factor inputs such as MOOE, personal services, and length of mains improve production capacity and technological advancement of DMUs. Between factor outputs, the volume of water delivered has the highest variability because it is not controlled and is primarily dependent on consumer demand. Increase factor inputs upsurge connection properties, as well as the volume of water, delivered. Hence, the Local Water Utilities Administration has also made significant efforts to increase the number of water districts to meet the demand. The result reflects those findings of Senante, Donoso, and Garrido (2016) that the variability intolerance of input and output variables reflects various efforts made by Chilean water and sewerage companies to improve the coverage and quality of wastewater treatment services.

Additionally, Garrido, Senante, and Arce (2018) found that Chilean water companies' average input and output improved from 2010 to 2016. The operating costs have risen during the research period. From 2010 to 2016, the number of employees has increased, and the network was extended. In contrast, between 2010 and 2016, the amount of water consumed per capita declined, while the total amount of drinking water provided surged due to population expansion. During the same years, the number of houses having wastewater treatment services increased significantly.

In the year 2014-2015,productivity recorded deterioration due to improper utilization of factor inputs and unimproved technological advancement. This could be the result of the limited investment that restraints DMUs to improve technological advancement. To become technically efficient, DMUs needed to increase or decrease factor inputs to increase the volume of water delivered and connection properties, meeting the demand of consumers as well. A similar analysis was applied to other water districts, yet, different policies could be achieved. The findings contradict those of Maziotis, Senante, and Garrido (2016), who found that technical change is the primary driver of productivity increase for English and Welsh water providers when the quality of service elements are taken into account (the shift of the efficient frontier). Marques (2008) found that significant investments in new infrastructures that did not exist resulted in higher operation and maintenance expenses.

In the year 2015-2016, most of the water districts were technically efficient. Largely, scale efficiency was the source of productivity gains for water districts. Also, technological advancement was considerably improved. On the other hand, deterioration of water districts is due to deterioration of managerial capacity controlling factor inputs. This result is consistent with the findings of Brettenny and Sharp (2017). They found that average productivity fell and that the decline was primarily due to a fall in production technology. Similarly, Byrnes et al. (2010, Brettenny & Sharp, 2017) found that increased water service provider technology was linked to improved infrastructure and technological capability.

In the year 2016-2017, the productivity of DMUs declined. Unimproved technological advancement was observed. Also, recorded lower regress technical efficiency was mainly caused by management inefficiency to control factor inputs, and decreasing variable returns to scale that deteriorate productivity gains of water districts. Hence, increase capital investment improves the productivity of DMUs.The results are in contrast to those of Silva and Thanassoulis (2011); they found that technical change was the primary motivator for the water industry in England and Wales to move toward the frontier. Similarly, Saal, Parker, and Jones (2007) observed that a significant increase in technical change in the English and Welsh water and sewerage industries resulted in a peak average technical change estimate. There was still considerable room for productivity gains through technological advancement.

In the year 2017-2018, the productivity of DMUs improved. The productivity gains during this period were due to increase investment to improve technological advancement and to improve managerial capacity. Noticeable, a slightly improved return to scale is due to an increase in factor input finances. Therefore, innovation and technology have a vital role in producing water districts.The findings are comparable to those of Yang et al. (2009, Tiange, Xiaolei, Honor, & Hui, 2015), who found that water resource utilization efficiency in Chinese water utilities was poor. The composite structure of the input elements was not optimal. Further, Kumar and Sarangi (2012) found that the overall average numbers of scale inefficiency suggest that the utilities in Urban India are not employing the efficiency of their resources is consistent with the findings of this study. Changing the level of operation for certain water utilities can help them enhance their performance.

Productivity gains of DMUs recorded slightly declined from 2014-to 2018. Mainly, the source of productivity gains of DMUs attributed to scale efficiency. Most of the DMUs achieved their productive capacity contributed to an increase in connection properties and volume of water delivered. Hence, an increase in capital investment is important to improve technological advancement and management aspects.The result is backed up by the findings of Worthington (2011) that the Australian urban water utility industries are entirely inefficient. Most water utility industries have been catching up with best practices in the field, and technology advancements have been slow. Furthermore, the advantages of improving the ability to integrate inputs and outputs in optimal proportions without changing the scale of processes are generally equal to the advantages of scaling up or down activities. This study aligns with the findings of Parker and Saal (2001) that England and Wales's water and sewerage utilities are becoming less productive. There was no capital investment in quality adjustment output. Similarly, Kumar (2006) claimed that the lack of water availability in urban areas is attributable to a lack of administrative capability.

V. CONCLUSION

The study evaluates the productivity of water districts in Region 12 over the years 2014-2018. The Malmquist productivity index is decomposed into technical efficiency change and technological change. Based on the result of the study, the researcher concludes that in the year 2014/15-2015/16, the average productivity of water districts improved by 26%. Most likely, productivity is benefited from increasing operation activity and technological improvement due to an increase in MOOE, length of mains, and personnel services (reference: table 1, table 2 and table 3). In contrast, the average productivity was declined by 31.4% in year 2015/16- 2016/17. Both efficiency and technological change were slumped (reference: table 4). Therefore, there has been poor utilization of inputs, failure to operate at the most productive scale size, and unimproved technological advancement. More so, in years 2016/17-2017/18, the average productivity of water districts increased by 21.7%. The sources of productivity gains were from technological improvement and proper input utilization (reference: table 5).

In addition, the firm productivity average (2014-2018) indicated that the productivity growth average of water districts is 98.1%. The increasing productivity is attributed mainly by scale efficiency (reference: table 6). However, it appears minimal gain. On the other hand, technological progress was inefficient but near to frontier. Perhaps, increasing inputs such as MOOE, personnel services, and length of mains (reference: Table 1) stimulate less efficient DMUs closer to the frontier. Thus, most water districts choose optimal level of outputs instead the adopting best practice technology. Moreover, 16.6% of the water districts fell in decreasing returns of scale they need to downsize operation to observe efficiency gains.

REFERENCES

[1.] Abrilla, N. and Yee, E. (2016). Technical efficiency of water districts in the province of Davao del Sur: A data envelopment approach. University of Mindanao, International Multidisciplinary Research Journal 1(2), 85-94. Retrieved from http://umindanao.edu.ph/journal/wp-content/uploads/2017/01/Technical-eff iciency-of-water-districts-in-the-province-of-Davao-del-Sur2.pdf

[2.] Alrashidi, A. (2015). Data Envelopment Analysis for Measuring The efficiency of Head Trauma Care in England and Wales. (Doctoral Dissertation, University of Salford). Retrieved from https://usir.salford.ac.uk/id/eprint/38013/1/DEA%20Thesis(AfafAlrashidi,2016).pdf

[3.] Afonso, A., Ayadi, M.and Ramzi, S. (2013). Assessment of Efficiency in Basic and Secondary Education in Tunisia: A Regional Analysis. ISEG Economics Working Paper No. 6/2013/DE/UECE , Available at https://ssrn.com/abstract=2228576

[4.] Balf, R., Lotfi, H., and Afrouzi, A. (2012). The interval Malmquist productivity index in DEA. Iranian Journal of Optimization. 4(1),273-274. Available atwww.ijo.iaurasht.ac.ir

[5.] Bretteny, W. and Sharp, G. (2017). Evaluation of the effectiveness of the National Benchmarking Initiative (NBI) in improving the productivity of water services authorities in South Africa. Water SA 44(1), 37-44. http://dx.doi.org/10.4314/wsa.v44i1.05

[6.] Carvalho, P., and Marques, R. C. (2014). Computing economies of vertical integration, economies of scope and economies of scale using partial frontier nonparametric methods. European Journal of Operational Research, 234(1), 292-307.

[7.] Charnes, A., Cooper, W., Golany, B., Seiford, L andStutz, J. (1985). Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. Journal of Econometrics, 30(1-2), 91-107. https://doi.org/10.1016/0304-4076(85)90133-2

[8.] Coelli, T.and Walding, S. (2006). Performance measurement in the Australian water supply industry: A preliminary analysis. Performance measurement and regulation of network utilities. https://www.researchgate.net/publication/37629049

[9.] Coelli, T. and Lawrence, D. (2006). Performance Measurement and Regulation of Network Utilities. Northampton, Mass, USA: Edward Elgar.

[10.] Cruz, E. (2004). Measuring Technical Efficiency in Research of State Colleges and Universities in Region XI Using Data Envelopment Analysis.. Retrieved from http://nap.psa.gov.ph/ncs/9thncs/papers/education_Measuring.pdf

[11.] De Witte, K. and Marques, R. (2010). Designing performance incentives, an international benchmark study in the water sectorCentral European Journal of Operations Research 18(2), 189-220DOI:10.1007/s10100-009-0108-0

[12.] Färe, R., Grosskopf, S. andRoos, P.(1997). Malmquist productivity indexes: A survey of theory and practice. Index Numbers: Essays in Honour of Sten Malmquist. Kluwer Academic Publishers, Boston, 127-190. DOI: 10.1007/978-94-011-4858-0_4

[13.] Fare, R., Grosskopf, S., Norris, M. and Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. The American Economic Review, 84(1), 66–83. Available at https://www.jstor.org/stable/2117971

[14.] Fuentes, R., and Lillo-Bañuls, A. (2015). Smoossthed bootstrap Malmquist index based on DEA model to c ompute productivity of tax offices. ExpertSystems with Applications,42(5), 2442–2450. https://doi.org/10. 1016/j.eswa.2014.11.002.

[15.] Garrido, R., Senante, M. and Arce, M. (2018). Assessing productivity changes in water companies: a compariso n of the Luenberger and Luenberger-Hicks-Moorsteen productivity indicators. Urban Water Journal 15(2):1-10. DOI:10.1080/1573062X.2018.1529807

[16.] GREENPEACE (2007). The State of Water Resources in the Philippines. Retrieved from https://www.greenpeace.org/seasia/ph/Global/seasia/report/2007/10/the-state-of-water-in-the-phil.pdf

[17.] Guerrini, A., Romano, G., Leardini, C., and Martini, M. (2015). Measuring the efficiency of wastewater services through Data Envelopment Analysis. Water Science and Technology, 71(12,) 1845-1851. DOI: 10.2166/wst.2015.169

[18.] Gulati, R. (2011, February). Evaluation of technical, pure technical and scale efficiencies of Indian banks: An analysis from cross-sectional perspective. In 13th Annual Conference on Money and Finance in the Indian economy (pp. 1-28).

[19.] Jarzębowsk, S. (2014). Efficiency and Return to Scale - A Concept of Using Deterministic Approach. Quantitative Methods in economics, 15 (2), 102-111. Retrieved from file:///C:/Users/DELL/Downloads/MIBE_T15_z2_11.pdf

[20.] Kulik, J. (2017). Technical efficiency and the Methods of its Measurement. Econometrics 3(57). 73-87. DOI:10.15611/ekt.2017.3.06

[21.] Kumar, S., and Gulati, R. (2008). Evaluation of technical efficiency and ranking of public sector banks in India: An analysis from cross-sectional perspective. International journal of productivity and performance management.

[22.] Maziotis, A., Garrido, R., Arce, M. and Senate, M. (2021). Total factor productivity assessment of water and sanitation services: an empirical application including quality of service factors. Environmental Science and Pollution Research, 28, 37818–37829 https://doi.org/10.1007/s11356-021-13378-8

[23.] Maziotis, A., Garrido, R. and Senate, M. (2016). Assessing the Impact of Quality of Service on the Productivity of Water Industry: a Malmquist-Luenberger Approach for England and Wales. Water Resour Manage 31, 2407–2427. DOI 10.1007/s11269-016-1395-6

[24.] Majunder, V. and Chetty, P. (2017). Performing MALMQUIST DEA in the hospitality industry. Project Guru. Retrieved from https://www.projectguru.in/tag/malmquist-dea/

[25.] Nourali, A., Davoodabi, M., and Pashazadeh, H. (2016). Regulation and Efficiency &Productivity Considerations in Water & Wastewater Industry. - Social and Behavioral Sciences 109 (2014) 281 – 289. doi: 10.1016/j.sbspro.2013.12.458

[26.] Rashidi, S., Barati, R.,and Kamali, Z. (2014). Measurement Efficiency by Malmquist Method in Data Envelopment Analysis. Trends in Applied Sciences Research, 9, 54-60.DOI: 10.3923/tasr.2014.54.60https://scialert.net/abstract/?doi=tasr.2014.54.60

[27.] Ray, S. (2004). Data Envelopment Analysis: Theory and Techniques for Economics and Operations Research.Cambridge, UK, Cambridge University Press.

[28.] Rubio, C., Lee, J. and Jeong, S. (2008). Water Resources Evaluation in the Philippines. Available athttps://www.researchgate.net/publication/322161060

[29.] Saal, D., Parker, D. and Jones T. (2007). Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985–2000. J Production Analysis 28, 127–139. DOI 10.1007/s11123-007-0040-z

[30.] Sanchez, J.J. (2018). Malmquist Index with time series to Data Envelopment Analysis. DOI: 10.5772/intechopen.74571

[31.] Senante, M., Donoso, G., and Garrido, R. (2016). Assessing the efficiency of Chilean water and sewerage companies accounting for uncertainty. Environmental Science & Policy 61, 116–123. Retrieved from http://dx.doi.org/10.1016/j.envsci.2016.04.003

[32.] Senante, M., Sancho, F., and Garrido, R. (2014). Benchmarking in wastewater treatment plants: a tool to save operational costs. Clean Techn Env. Policy 16, 149–161. doi: 10.1007/s10098-013-0612-8

[33.] Simões, P., Cruz, N. F., and Marques, R. C. (2012). The performance of private partners in the waste sector. Journal of cleaner production, 29, 214-221.

[34.] Silva, M. and Thanassoulis, E. (2011). rPoductivity change in the water industry in Englandand Wales: application of the meta-Malmquist index . Journal of the Operational Research Society 62, 2173–2188. Available at ttps://www.researchgate.net/publication/227470365

[35.] Tatje, E. and Lovell, C. (1995). A note on the Malmquist productivity index. Economics Letters 47(2):169-175. DOI:10.1016/0165-1765(94)00497-P

[36.] Tiange, S., Xiaolei, Z., Hongru, D.,and Hui, S. (2015). Urban Water Resource Utilization Efficiency in China. Chin. Geogra. Sci. 2015 Vol. 25 No. 6 pp. 684–697. doi: 10.1007/s11769-015-0773-y

[37.] Tsebe, M. and Biniza, S. (2015). Analyzing Total Factor Productivity Growth for South Africa's Manufacturing Sector Using a DEA-Based Malmquist Productivity Index. Retrieved from file:///C:/Users/DELL/Downloads/Analysing_Total_Factor_Productivity_Grow.pdf

[38.] Uddin, N. (2015). Productivity growth, efficiency change, & technical progress of a corporate sector in Bangladesh: A malmquist output productivity index approach. International Journal of Economics and Finance, 7(8), 240-255.

[39.] Worthington, A. (2015). Efficiency, technology, and productivity change in Australian urban water utilities Retrieved from

[40.] Worthington, A. (1999). Malmquist Indices ofProductivity Change in Australian Financial Services. Journal of International Financial Markets, Institutions and Money9(3):pp. 303-320.

[41.] Zschille, M., andWalter, M., (2011). The Performance of German Water Utilities: A (Semi)-Parametric Analysis. Retrieved from https://pdfs.semanticscholar.org/52fc/c83842afe0bc0b289e4b57564ab80503125d.pdf