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EFFICIENCY ASSESSMENT OF WATER PROVIDERS BASED ON THE INSTALLATION SCENARIOS OF PREPAID METERS USING DEA APPROACH

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Abstract: In recent times, there is a momentous increase in the installation of prepaid meters to the customers for either new water connection or for replacement of current postpaid meters with prepaid system. This research evaluates firstly, whether there is a significant difference in the performance of the Palestinian water providers based on the level of installation of the prepaid meters. Secondly, calculating the efficiency scores using Data Envelopment Analysis (DEA) based on the scenarios of prepaid level. The multivariate analysis of variance (MANOVA) shows that there are significant differences in the non-revenue water and debt collection performance indicators of water providers based on the prepaid meter installation. A correlation analysis demonstrates that there is negative significant relationship between the roll-out of prepaid meters, and the performance indicators of non-revenue water, per capita consumption, financial loss, staff inefficiency and water intermittent in the summer season. The (DEA) results reveal that minimum cost, maximum debt collection efficiency, and maximum number of served population, can be achieved through restructuring the water providers by changing their size to medium size and changing their current meters to prepaid system, other things being equal.

Keywords: DEA analysis, efficiency assessment, multivariate analysis, palestinian water. providers, prepaid meters.

Introduction

Recently, there is high propensity to recognize the importance of distribution responsibilities and authorities among water entities to promote effective water governance, and to increase the efficiency in various water institutions. The Palestinian Council of Ministers "CoM" endorsed an action plan for institutional and legislative restructuring in the water sector at the end of 2009 (Orgut & Fishing Consulting Group, 2013). The purpose of the Palestinian water reform was to segregate the duties in the water sector by splitting policy function from the regulatory function. Therefore, each water entity would be able to do its job specified in the sectorial strategic plan. The expectation from that reform was to have an efficient, organized, and sustainable Palestinian water sector.

To put the Palestinian water reform in the action s, Declared Water Law 2014 was approved to specify the role and the responsibilities of each water institution. The major player in the sector is the Palestinian Water Authority "PWA" which takes on the ministerial role so as to ensure better planning and in developing the sector. The Water Sector Regulatory Council "WSRC" is responsible for monitoring the performance of water services providers, such as approving water prices, to ensuring that service is provided according to the standards and at affordable prices. The third stakeholder in the water sector is the water service providers that include municipalities, regional utilities, joint water councils and water associations. Those providers would be are in charge of water services delivery to the end customers and in managing the local water networks (PWA, 2014).

The Declared Water Law 2014 assigned the role of establishment to the PWA- in coordination and cooperation with the relevant stakeholders and for the regional water utilities to provide water and wastewater services to the end customers. The term establishment means that changing the current structure and ownership of current water providers from municipalities, service councils, and water associations to the fully legal and financially independent utilities. Changing the structure involves also merging the small water providers into large water providers to achieve better efficiency, provide high quality of water services, expand the water services to new areas, and increase debt collection. The Palestinian Declared Water Law 2014 calls for merging current water providers from various structures and of different sizes into large regional utilities to achieve economy of scale, high quality of services, and diminish current challenges faced by the water sector.

The main challenge of the Palestinian water sector is lack of good performance of water providers (WSRC, 2018). For instance, the average financial loss in water services was near to 30%, debt collection efficiency less than 65%, non-revenue-water near to 35%, and some water providers had non-revenue water by 50%. Lack of good financial performance on the part of the water providers had affected the Palestinian people as they paid the cost of non-revenue water, consumed less quantity than the standard quantity, decreased the quality of service, limited expansion of the water services into new areas, and lowered decrease the overall living standards.

Among these conditions, CoM and PWA with the support from international donors started to encourage the water providers to increase the cash collection from their end customers especially those who had accumulated water debts and unpaid invoices (PWA, 2018). Without cash inflow to the water providers, it would be difficult to continue providing high quality water services to the customers and to ensure sustainability. Cash inflow is the lifeblood of any service providers. It is necessary because it would be is converted into payment for things needed when providing water services, such as operating and maintenance expenses, staff salaries, rents, and other administrative expense. Therefore, the ability of the water providers to increase the percentage of water bills collections from their customers is an indicator of management efficiency and service sustainability.

The main driver of cash collection efficiency is installing prepaid water meters on the customers' site instead of the currently installed postpaid water meter (Murrar, 2017). This means that the customers would have to pay in advance all the amount due for of water service to the water providers, and also pay part of the accumulated debt for previous consumption. The result of this policy was that after a given period of time i.e. few years, the water providers would have no invoices due or accumulated debts from their customers.

The PWA, upon instructions from the CoM, encouraged water providers to replace existing postpaid meters with prepaid water meters. The PWA deducted the costs of these meters from the debts of the water provider who had replaced the postpaid meters with the prepaid ones. In other words, the PWA finances the installation of prepaid meters for water service providers so that they would be able to pay the bills of water purchased from the wholesale – bulk- provider as well. The overall direction is to increase the prepaid meter installations onto the customers' sites. According to the PWA, there were about 12,000 prepaid meters under implementation but in 2019 this produces the total of prepaid meters, about 50,000 meters, would have been installed. With this quantity, the percentage of prepaid meters would be 20% against all other meters (WSRC, 2019).

So far, two strategic decisions were then under implementation in the Palestinian water sector. The first one was preparing a roadmap for merging the current providers into regional utilities, and the second was replacing the the postpaid meters used at that time with prepaid meters. The purpose of this research hence is to evaluate whether there are significant differences in performance indictors of the water providers based on the percentage of the installation of prepaid meters. In other words, the research would test the effect of prepaid meters on the performance of the water providers. Thereafter calculating the efficiency scores of the scenarios that are developed based on the level of prepaid meters installation, and the size of the water providers.

Palestinian Water Providers

The WSRC implemented a large project to identify all Palestinian water providers in the West Bank and the Gaza Strip. The purpose of that project was to conduct a national review of tariff structures, adopt cost calculation methodologies, and connection fees structures of all Palestinian water providers. The data showed that there were 272 water providers in various ownerships and legal structures, which are water and wastewater utilities, water departments within municipalities, water departments within village councils, joint service council's, and water cooperative associations (WSRC, 2018). Regional utilities and cooperative water associations are semi-independent entities and they reported to their board of directors. The joint service councils report to the ministry of local government "MoLG" directly. The water departments within the municipalities reported to the mayor, while the water departments within the village councils reported to the village council manager respectively. Both municipalities and village councils reported to the ministry of local government.

Palestinian water providers are divided into three size categories according to the number of customers they serve (WSRC, 2015). The small size water providers are those who serve less than 2,000 customers. They are mainly small village councils and small municipalities that provide municipal services including water in small towns. Medium - sized providers represent those who serve from 2,000 to 8,000 water customers, and the large - size provide water services to more than 8,000 families or customers while the larger water providers such as regional utilities are mainly located in the big cities and they provide water services to many areas.

Performance Indicators

The performance indicators can be defined as "measures that are monitored in order to determine the health, effectiveness, and efficiency of an institution" (Dolence & Norris, 1995). The performance indicators are used to assess the efficiency and effectiveness of water providers as well. The term efficiency may refer to using the minimum amount of input to produce the highest amount of output; while achieving the realistic targeted objective during a given period of time according to the plan is a measure of effectiveness (Alegre, 1999). The water provider utilizes the resources optimally to deliver maximum service quality and quantity to the people and this is an indicator for efficient management. Efficiency requires continuous reducing of the number of unnecessary inputs such as operating costs used to provide water service.

To measure the efficiency, productivity and health of water service providers, the International Water Association (IWA) issued a book outlining key performance indicators for measuring various aspects of water service providers' performance (Alegre *et al,* 2013).

Table 1: Summary Palestinian water providers by location, structure, and size

Region Name	Municipal Department	Joint Council	Village Council	Cooperative Association	Regional Utility	Small Size	Medium Size	Large Size	Grand Total
North	34	4	91	2	0	115	12	4	131
Middle	17	2	35	1	1	46	9	1	56
South	24	3	32	0	1	46	12	2	60
Gaza	24	0	0	0	1	11	8	6	25
Total	99	9	158	3	3	218	41	13	272

Measurement of performance indicators is essential to improve the quality of water and sanitation services. In addition, key performance indicators help national policy makers who work in the water and sanitation sector to monitor and control the level of implementation of these policies and targets within the integrated water resource management perspective, for example, to find out whether the non-revenue water indicator or the water leakage percentage decreased nationally to the planned percentage. The indicators can also be used in planning investment, drafting regulatory tools, developing new standards, allocating financial resource and improving overall performance.

Some performance indicators measure technical aspects of water providers, such as the daily per capita consumption of household indicator. This indicator is important because the quantity of water delivered and used by households influence hygiene and therefore public health. The indicator gives a good picture on the ability of water provider to deliver the required quantity to the population. Another technical indicator is also the non-revenue water. This indicator calculates the difference between water purchased and produced on the one hand; and the quantity of water sold on the other hand. In other words, this indicator measures the amount of water leaked and stolen from the network. The ability of the water provider to minimize this indicator ratio reflects the management efficiency in utilizing resources to provide the maximum possible service to the population.

Of course, there are other indicators that measure the performance of a water provider such as network coverage ratio, i.e. the number of people who have access to the water service relative to the total number of population in the area. Some water providers have limited financial resources, and therefore, were unable to expand their water networks to serve the population in the area. The ability of a water provider to cover the water service to everyone in the service area is one of the important performance indicators that measures the capacity of the water provider in investment allocation and development process. The staff productivity indicator measures the ability of water service provider to utilize the team to serve as many people as possible. The indicator is measured by dividing the number of served customers by the number of water staff members.

Some indicators tackle the financial aspects, such as the ability of a water provider to collect accumulated debts and bills from the customers. This indicator measures the amount of cash receipts relative to total water sales. Other financial indicators such as the working ratio, measures the ability of a water provider to cover water costs from water revenues. This indicator is linked to other financial indicators such as the sales price and the cost of cubic meter water sold. Other type of indicators are used to measure the water quality such as chlorine percentage, nitrate concentration and so forth.

In Palestine, the “WSRC” collects the performance indicators data from water service providers serving various Palestinian areas. The council verifies and validates these data after comparing them with the water provider’s records. A technical team then calculates the performance indicators based on the verified data, thereafter, the council publishes these indicators in the annual report. The annual report covers water service providers providing water services to about 80% of the total Palestinian population.

Prepaid Water Meters

The impact of prepaid water meters on the performance of water service providers is typically something of a mystery. In Palestine, many water service providers purchase and install the prepaid water meters into their customers. The prepaid system forces the customers to pay the water bill in advance to the provider. In case a customer has an unpaid bill the water provider can recover part of the debt at each time the consumer charges the water meter. This means that after few years, the water service provider will be able to collect all its accumulated debts from the consumers concerned.

According to water service providers, the installation of prepaid meters has significant positive and direct impact on their performance indicators and their management efficiency. For instance, because of the high debt collection rate, a substantial cash inflow goes to the water service provider's treasury. The availability of funds in the treasury will enable them to realise their potential through expansion activities like expanding the water network and thus serving new areas and neighbourhoods. Also the availability of funds leads to improved quality water service especially through purchasing additional pumps and control systems, as well as repairing the water network to reduce the leakages.

Other benefits of prepaid meter system are that water providers generally don't need additional staff members to issue invoices and collect the debts; because the bills are paid at the payment points such as in the supermarkets, municipal offices, and so on. Thus, the costs of staff salaries and operating expenses are reduced. According to literature, installing the prepaid meters leads the customers to rationalize their consumption, and thus as a result supply of water could be distributed to other areas suffering from water shortage.

In contrast, consumer rights associations consider installation of the prepaid water meters to the customers as a violation of human rights. The United Nations General Assembly also recognized that water supply to every person must be adequate and continuous to cover personal and household uses, including water for drinking, washing, food preparation, and personal and household hygiene. Therefore, some water providers responded to civil society associations and stopped installing the prepaid water meters.

While, some water providers made the installation process as optional for their consumers, but kept trying to convince the customers to accept installing the prepaid meters through offering some incentives and discounts. Those water providers argue that the water service will remain connected to the household customers for two or three days, so long and enough time for the consumer to charge the water meter again. On the other hand, the prepaid meter system is optional for the household customers, but it is a mandatory for the commercial and industrial customers, as well as for consumers who have accumulated debts.

The civil society associations argued that because the infrastructure is not ready yet in Palestine, then providers should not be installing prepaid water meters. For instance, the water service is not available in a continuous mode, and in some areas the water service may arrive every month or more. The prepaid meters installation may increase water theft and illegal connectionsand this would increases the financial losses to water providers instead of reducing their operating costs.

Hence, this research examines the effect of prepaid meters on the performance indicators of the water providers in Palestine. The research evaluates whether there are significant differences in performance, either positive or negative performance between the water providers who have prepaid meters and the water providers who do not have prepaid meters. For example, installing prepaid meters may increase water thefts because the consumer can not afford to pay in advance, which means increasing the non-revenue water indicator. In contrast, the installation of prepaid meters may reduce the non-revenue water indicator due to availability of funds for the water providers. Thus they can repair the network pipes, prevent network leakages, and purchase tools and devices to monitor thefts. Therefore, the impact of prepaid meters installation on the performance of the water providers is important to the national decision makers, to water providers, as well as to the civil society associations.

DEA Analysis

In recent years, there have been several studies that measured the efficiency in different fields using the data envelope analysis "DEA". The DEA tool was first introduced by Charnes, Cooper, and Rhodes in 1978 to develop measures of decision making efficiency for groups of entities or decision making units (DMUs) (Charnes *et al.,* 1978). The DMUs are entities that work in different sectors and are responsible for changing the input variable(s) into output variable(s) and therefore the DMUs performance are to be evaluated and ranked (Cooper *et al.,* 2011). The DEA has become a very popular technique for efficiency measurement because of its ability to measure relative efficiencies of multiple-input and multiple-output for different DMUs (Jablonský & Josef, 2016).

A variety of research studies have been conducted to evaluate various DMUs which work for instance in the education sector. The efficiency of universities was measured using the DEA model (Wonga & Kuaha, 2011). About 16 inputs and outputs were used to measure the efficiency of teaching and research in the universities, thus the model differentiated between efficient and inefficient universities in that study. The DEA also scored the US school students participating in International Student Assessment (Aparicioa *et al.,* 2019); as well as evaluated the UK universities in the field of chemical engineering (Gosálbez *et al.,* 2019). Therefore, it allowing higher education institutions to understand their weaknesses and to improve their performance by providing the decision maker with information on the stability of each DMU (Milan Hladík, 2019).

Many scholars have conducted various studies using DEA techniques in various productive sectors. Zhou *et al*. (2019) investigated the meteorological factors and human activities that influence the pollution emission. The efficiency in dairy production unities has been calculated in Cuba (Herrera *et al.,* 2013) and the efficiency of dairy farms has been tested in Greece as well (Siafakas *et al.,* 2019). The results revealed that inefficiency ranged between 22% to 100% with an average 83% in the sample farms. Other researchers ranked the efficiency scores of DMUs in sectors such as application software (Chatzigeorgiou & Stiakakis, 2010), hospitals (Akono *et al.,* 2013), banking system (Henriques *et al.,* 2018), and hotels (Sestayo & Castro, 2018).

In the water supply sector, there are many research papers that measure the performance of water providers in developing countries (Al-Assa'd & Sauer, 2010). The studies always examine the economies of scale and scope, public private ownership and the impact of regulation (Cetrulo *et al.,* 2019). This research adds to the literature by measuring the efficiency scores in a small developing country that has a large number of water providers compared with the number size of the population. The Palestinian water providers in this study also have five ownership structures owned privately, by municipalities, utilities, associations and joint service councils.

The impact of the ownership structure on efficiency was also investigated in developed countries such as Italy and Portugal. The research paper assessed the efficiency by comparing 88 water utilities from both the Mediterranean countries to draw policy implications (Cruz *et al.,* 2012). To recommend the optimal market structures and water provider size in German potable water supply, the DEA model used a cross-sectional sample of 364 German water utilities (Zschille *et al.,* 2014). Different efficiency scores were achieved by private companies public-private partnerships, and public companies in Spain when environmental variables were considered in the model (Gómez *et al.,* 2012). The results indicated that public-private partnership structure is not less efficient than the fully private structure or fully public ownership.

General speaking, the common feature of all these DEA studies whether conducted in developed or developing countries is that, they consider the efficiency of water utilities according to the ownership and size (Varela *et al.,* 2016). In addition to the ownership structure and size of water providers, our research has proposed the type of water meters that could be installed on the customers' site while regardless whether it is a prepaid or postpaid meter system. The research paper showed that prepaid water meters have a significant impact on the water utilities performance and on the quality of water services in Kenya (Hanjahanja & Omuto, 2018). So it is important to include prepaid meter variable in scoring the efficiency of water service providers in Palestine, especially as no previous research has measured the efficiency using the water meter type and because there is an increase in the installation of prepaid water meters in developing countries by water providers in the hope of enhancing their efficiency, and improve their financial position (Sherry *et al.,* 2019).

Data & Methodology

In order to contribute to the literature in water sector, this paper focuses on the Palestinian water providers. They are particularly suitable for comparing performance since there are water DMUs with different features in ownership structure, size, service provided, location, density and so forth. Guerrini *et al.* (2010) measured factors affecting the performance of water utilities that have different features such as public and private ownerships, and of different size, as well as the mono- and multi-utilities in the water sector in Italy. The chosen method was based on financial ratios that cover the profitability, investments, tariffs, efficiency and financial leverage of water providers. Singh *et al.* (2014) proposed the performance indicator system in addition to the data envelopment analysis to assess water providers for Indian water utilities. In addition to data envelopment analysis, our research introduces the technical and financial performance indicators that are based on the international networks such as World Bank IBNET and IWA system of performance indicators (IWA-PIs). These indicators can measure the financial position, quality of water service, and the technical performance of water providers.

Data

In Palestine, the mandate of WSRC is to ensure the quality and efficiency of water and wastewater services provided to the customers (PWA, 2014). To achieve its objective, the council collects annual financial and technical data from a large sample of Palestinian water providers who provide water service to about 80% of the Palestinian population. The council issues annual performance report that contains the financial and technical performance indicators (WSRC, 2017). The WSRC cross-sectional data was used previously to evaluate the performance of 63 water providers (Murrar *et al.,* 2017). The data used in this research is the WSRC performance indicator reports and WRSC tariff database. About 200 observations for 113 water providers who delivered water service to different Palestinian areas during years 2016 and 2017 were made.

Methodology

The prepaid meter system has a direct impact on various aspects of the water providers' performance. When a household pays water bills in advance, this will increase the amount of cash with the water service provider, increase revenue collection, as well as decrease accumulated debt on the end customers. With these favourable high cash conditions, water providers can deliver water service to new areas, increase the quality of service through purchasing sufficient quantities of water, reduce water losses by repairing old networks and renew depreciated pipes and purchase new water distribution software technology. This will increase the water providers' profit and reduce the accumulated losses as well as increase the employee's productivity. Therefore, the prepaid meter system has strong impact on many variables associated with various performance indicators of water service providers. To assess the relationship among prepaid meter system and core performance indicators as well as technical efficiency for water providers, this research considered two techniques in its methodology.

First Technique

The first test was conducting multivariate analysis of variance (MANOVA), that is used when there are several dependant variables predicated by one or more independent variables (Rencher *et al.*, 2003). In this paper, the MANOVA shows the relationship and significant impact of prepaid water meters and size of water providers as predictor variables on core performance indicators as response variables. The core performance indicators of water providers are: non-revenue water and debt collection efficiency (Murrar, 2017). Expressed in other term, this test can specify whether there are significant differences in these core performance indicators of the Palestinian water providers' based on the installation levels of the prepaid meters and the size of water providers. To support MANOVA assessment in this research, a correlation test is conducted to find relationship between the roll-out level of prepaid meters, and other performance indicators such as average price, water consumption, staff productivity, and working ratio "gross profit" operating cost, coverage ratio, and water availability in summer.

The first step in evaluating the water providers' efficiency and all other components of water providers' sustainability by using the performance indicators (Haider *et al.,* 2013). The performance indicators that published by WSRC used in this research (WSRC, 2018). The indicators cover mainly three performance areas of water providers: Firstly, financial performance area which contains the indicators of average sales price, operating cost, working ratio and collection efficiency. Secondly, performance area of service quality that has coverage ratio, intermittent water supply in summer season and per capita consumption. Thirdly, efficiency of water providers which includes indicators such as non-revenue water, staff productivity and number of population per water connection are taken into account..

Second Technique

The second test is conducting the Data Envelopment Analysis to score the efficiency of water providers based on the level of installation of the prepaid water meters to the customers. For this test, the water providers were divided into five broad categories according to the installation levels of the prepaid water meters: Level "E" contains those that use zero prepaid water meters. This means that all water providers in this category install and manage post-paid meters. Level "A" on the other hand, includes all water providers that install and use the prepaid water meters only to their customers. Therefore, no post-paid meters are implemented by water providers in this category. Level "B" consists of all water providers that manage small level of prepaid meters. Under this category the percentage of installed prepaid meters is 33% or less. Level "C" constitutes water providers who install and manage medium percentage of prepaid water meters i.e. 33% to 66% are prepaid meters and the rest are postpaid meters. Level "D" involves all water providers who employ high percentage of prepaid meters i.e.

range from 66% to 99%.

WSRC divides the water providers into three categories based on the number of connections they serve (WSRC, 2015). The all water providers who serve less than 2,000 water connections. Medium size category, in which water providers under this category service from 2,000 to 8,000 connections and the large size of water providers serve 8,000 active connections or above. Most water providers in Palestine are small size and they serve less than 2,000 customers. At the end of each year, the number of water providers varies in different size categories. Some water providers move from small size category to medium size category because the number of their customers' increases, to above 2,000 customers or connections. Other providers may move from medium size category to large size category depending on the number of customers they have at the end of the year as well.

A water provider is treated as production unit or DMU which changes the input into out. Surender Kumar (2010) considered the choice of input is based on the availability of data. The available data was related to the operating and maintenance cost and the capital expenditure incurred the last five years. The output variable that achieved to measure the efficiency was unaccounted for water. Kulshrestha and

Table 2: Main features of each cluster

Installation Level of Prepaid	% of Prepaid Installed	Water Provider Size	Operating Cost Amounted in (NIS)	Number of Served Population	Revenue Collection Amount (NIS)	Average of Staff Members
Level "E"	Zero	Small	1,123,820	7,645	442,243	6
Level "E"	Zero	Medium	3,757,075	34,624	1,612,057	17
Level "E"	Zero	Large	22,174,759	183,514	11,917,923	92
Level "D"	Low	Small	693,763	7,368	517,616	4
Level "D"	Low	Medium	2,472,780	24,501	1,885,882	8
Level "D"	Low	Large	18,343,002	193,288	11,446,647	140
Level "C"	Medium	Small	735,914	7,021	347,930	3
Level "C"	Medium	Medium	3,265,461	32,730	3,012,192	15
Level "C"	Medium	Large	6,514,039	64,721	6,624,671	19
Level "B"	High	Small	1,010,141	8,440	494,450	4
Level "B"	High	Medium	2,682,118	28,234	2,767,396	17
Level "B"	High	Large	3,595,277	43,950	3,897,914	23
Level "A"	Full	Small	267,146	2,838	316,182	1
Level "A"	Full	Medium	1,437,571	31,100	2,106,021	15
Level "A"	Full	Large	6,580,403	59,500	8,318,671	17

Vishwakarma (2013) employed three DEA models. The input variables contained operating cost, staff members per 1,000 connections and non-revenue water quantity; while the output variables were the number of connections, produced quantity and network length. Others focused on revenue collection, non-revenue water and the repair cost as the indicators that used to measure the performance of water utility in Malawi (Banda & Mwale, 2018).

This research employs the operating and maintenance cost as input variable. The output variables are the number of people served and the amount of revenue collected. The input factor is selected because of its importance. This includes all the operating, administrative and even parts of capital expenditure, because many water providers in Palestine implement the on cash basis practice in their accounting system. As for the output variables, the debt collection variable includes revenue amount, and revenue collection. It therefore reflects the water provider's ability in selling, pricing water service and collecting the accumulated water debt. The second output factor is the number of serviced population, which also reflects the ability of water provider to sell water quantity to a large number of customers, as well as provide water service to high coverage area.

DEAP software version 2.1 is a free software used for efficiency analysis developed by the Centre for Efficiency and Productivity Analysis (Guerrini *et al.,* 2015). This software package enables the user to define the values of input and output variables, and the number of stages are required to solve the linear programming model problem, as well as selecting constant or variable return to scale (Murrar *et al.,* 2017). According to available literatures, some authors in this field use input-oriented model which provides potential improvement in the efficiency by reducing the input consumption with the same amount of outputs. Other scholars use output- oriented model when increasing the amount of output in the production process, given a specific amount of input. For water providers in this research, outputs are measured by the revenue collection from customers, and by the number of people or size of the population served in the area. On the other hand, input is measured by operating cost. This means that both input and output are not constant, and they vary over time. Therefore, this research estimates the efficiency scores for both input-oriented and output oriented of each decision making unit.

Results

Multivariate analysis is used in this study to investigate the impact of roll-out the prepaid water meters by the water providers and their size on the performance indicators of their key functional areas. Appendix Table A1 shows that the null hypothesis for this test is that the observed covariance matrices for the dependent variables are equal across groups. The Box's M value is 27.585 and the *P* value is .112 and is non-statistically significant results. So the values failed to reject the hypothesis and meet the assumption of equal covariance matrices for this MANOVA (Haase *et al.,* 1987). Appendix Table A2 shows Wilks' Lambda = 0.004; this means that there is a statistically significant difference in the performance of the Palestinian water providers based on their size and on the installation level of the prepaid meters.

The Wilks lambda in Appendix TableA2 is a test of the overall multivariate significance, but there is a need to test between subject's effects in each functional area of water providers. The multivariate test in Appendix Table A4 shows that, the performance indicator of non-revenue water and debt collection have significant differences between their groups based on the installation level of prepaid water meters, where $P < 0.05$. It is clear that the roll-out of prepaid water meters is exogenous to the performance of water utilities in terms of non-revenue and debt collection.

The results of this study show that there is a significant difference between the water providers who have different levels of prepaid meters in debt and bills collection. The collection efficiency of water providers who do not have prepaid meters is 52.28%, while the collection rate for the those who have prepaid meters only -- without the postpaid meters it is 104.44%. This implies that the collection efficiency doubles the percentage in the case of installation of the prepaid meters.

The results reveal that the non-revenue water for the providers who do not have prepaid meters is 31.34%, while the non-revenue water level for those who have only prepaid meters is 14.38%. This means that the water providers who installed prepaid meters have the ability to reduce the water loss by about 54%, compared with those who did not.

The results also show that there are significant differences in the percentage of gross profit among water providers based on the level of prepaid meters. The higher the proportion of installed prepaid meters, the greater the percentage of gross profit.

Table A5 in the Appendix shows three main finding in this context: The first result indicates that the higher the percentage of prepaid meters is, the lower the average per capita consumption becomes. The second result demonstrates that there is negative relationship between the level of prepaid meter installation, and the water intermittent in the summer season. The third finding from the table shows that there is a significant and positive relationship between the average sales price and the level of prepaid meter installation, while no significant relationship appears between the average cost of cubic meter and the roll-out level of prepaid meter.

Table A3 in the Appendix which scores the water providers according to the efficiency shows that the average of CRSTE is 0.594; VRSTE is 0.762; and SCAL is 0.794. The results imply that, on average, the Palestinian water providers can reduce the inputs by about 40% (100%–59.4%) without any decrease in output.

Explanation and Discussions

The main results of this research can be explained in each performance area of the water providers. The performance areas are: debt and bills collection, non-revenue water, gross profit, daily consumption, staff productivity, service coverage, costing and pricing, as well as efficiency scoring.

Debt and Bills Collection

The primary purpose of installing prepaid meters by water providers is to increase the accumulated debt collection, as well as to collect the water bills on a regular basis. Increasing the percentage of water debt and bills collection is important for the water provider and reflects its efficiency in the management. The higher the percentage or level of prepaid meters compared with the postpaid meters, the higher the collection percentage of debt and bills from the subscribers.

In this study, the number of water providers who did not have prepaid meters is 57. They delivered water service to about 2.8 million people. While the other 32 water providers in this study were those who had different rates of prepaid meters and supplied water service to about 1.2 million people. This is an interesting result for water providers without prepaid meters and suffered from debt accumulation and poor monthly bills collection and they have data on the expected percentage of debt and bills collection based on the level of prepaid meters installation. The water providers could then decide the percentage of prepaid meters that they would like to install based on the installation cost of these prepaid meters and their benefits. The central government would also have additional information that is necessary in planning for the water sector at the macro level, such as feasibility, the cost of installing prepaid meters at the national level. The results of this research are consistent with a previous study which concluded that the prepaid water meter system has a statistical significant impact on debt and bills collection of the Palestinian water providers (Murrar, 2017).

Non-Revenue Water

The non-revenue water is a key indicator of the efficiency of the water provider's management. The lower the water loss, the more likely the water provider will be able to reduce water production costs and serve a larger population. Palestine suffers from water shortage and high water losses, which could reach 50% in some areas. For this reason, non-revenue water indicator is important for the water provider and for the central government as well as for the Palestinian water customers.

The prepaid meters system increases the flow of funds from the customers to the water provider. This will enhance their ability to adopt methods and strategies to reduce water loss. For example, because of the availability of funds, the water providers will be able to purchase software and technology to reduce water loss, avoid water leakage though preventive maintenance system, hire non-revenue water team, and so on. There are also some types of prepaid meters that synchronize the details of consumption data to the water provider's database on timely basis. Therefore, if the consumption is increased for a particular subscriber, a water provider will examine the reasons for this deviation and fix the problem in the case of water leak. The results of this study are important for water providers, especially those who have water intermittent problem in the summer season for long periods. Reducing water losses in general will lead to increased quality of service, and also to ensure fairness in the distributed.

Gross Profit

The gross profit indicator is one of the most important financial indicators for water providers. It measures the ability of the water provider to achieve sustainability in the service delivery. The accumulated financial losses always limit the ability of water provider to expand its services and provide the service with better quality. The working ratio in this study measures the ability of water providers to cover the operating and maintenance costs from their revenue within the year. When working ratio equals 1; that means revenue equals costs. However, if it is less than 1, the revenue is higher than cost. So there is a profit margin that can be used in capital expenditures to expand the water network and increase the quality of service.

The prepaid category generates gross profit and can allocate part of the funds for capital expenditures, while the postpaid category incurs a financial loss and the revenue insufficient to cover the operating and maintenance cost. The results also indicate that about 40 water providers who delivered the service to about half of the Palestinian population in this study had a working ratio more than 1. This explains that half of the Palestinians receive water service from providers who incurred financial loss.

Daily Consumption

The average daily per capita consumption is a good indicator for the availability of water resources and the extent to which a water provider can supply water services to the population. Some areas faced from water shortage problem. The daily per capita consumption in such areas is about 40 liters per day; while the average per capita consumption that recommended by the World Health Organization is about 120 liters per capita per day.

The average per capita consumption in the areas of water providers with no prepaid meters is 85.88 liters per day; while that consumption in the areas with only prepaid meters is 60.06 liters per person per day. This demonstrates that there is a difference in average water consumption by about 30% between the two categories of consumers. Studies showed that the installation of prepaid meters led to a decrease in water consumption by 65% (Public Citizen, 2017).

Generally, the decrease in average water consumption in the areas with prepaid meters can be attributed to the lack of water availability, the low non-revenue water percentage, and the prepaid meter system that reduces the average consumption. These results are important especially for the NGOs working for human rights and calling for the rights of people to receive appropriate and sufficient water quantity. At the same time, the results are also important for the government to examine the possible consequences and benefits of increasing or decreasing water consumption and useful for water providers to know the expected quantity that can be saved as a result of installing prepaid meters, and that water is therefore distributed fairly to all customers.

Staff Productivity

One factor in increasing the efficiency of a water provider is by increasing staff productivity. The staff productivity indicator can be defined as the number of employees who serve 1,000 water connections. The higher the number of employees serving 1,000 water connections is, the lower the staff efficiency is. Appendix Table A5 shows that there is negative and significant relationship between the staff productivity of water providers and the levels of prepaid meters installation. The water providers without prepaid meters need 5.265 employees to serve 1,000 water connections, while water providers with prepaid meters only need 3.56 employees to serve the same number of water meters.

In fact, the water providers who used prepaid meters needed less administrative effort than the than those with postpaid meters, as no employees were needed to distribute invoices to consumers and collect bills and accumulated debts. The consumer load credit balance of water quantity was done through charging the water card at the supermarkets and other sales centers. So, in managing prepaid meters a water provider would need less employees by about 32%. This information is necessary to some water providers with overstaffing issue and for those who had plans to install prepaid meter system to stop the hiring process and looking for alternatives how to existing staff such as transfer them to other departments and increase their efficiency.

Service Coverage

Increasing quality of service is a basic input in achieving consumer satisfaction and thus creating the incentive for those consumers to continue paying for water services. If more prepaid meters that installed, then it would less frequent that water is disconnected in the summer season.

Costing and Pricing

The percentage of gross profit or loss is affected by the sales price and the cost of purchasing and producing the water cubic meter. The results indicate that the average sales price of cubic meter for water providers withou prepaid meters is 3.49 NIS but the cost per cubic meter is 4.17. Conversely, those with prepaid meters, their price per cubic meter was 4.52 and their cost was 4.35.

The main cost components of the water cubic meter in Palestine are the purchase price of water, as well as the energy costs of pumping water into the network. Therefore, these expenses are borne by all water providers, regardless of prepaid or postpaid meter systems. As for prices, the average price of cubic meter is higher for water providers who used prepaid meters because they did not follow the incremental segments. Those providers have one segment at a high price, unlike water providers using postpaid meter system, where they sold water based on the incremental segments. Therefore, the average price for prepaid water providers is higher than the average price of providers with postpaid providers.

Efficiency Scoring

So far, the results of multivariate analysis and correlation test revel that there is significant relationship between some performance indicators and the level of prepaid meters roll-out. The DEA efficiency score can be summarized to show how much a water provider can maximize output without input addition. The technical efficiency is estimated by maximizing the output subject to constant input and measured based on the VRS (input oriented and output oriented). Efficiency scores for both input-oriented and output oriented of each cluster of the water providers are estimated as in the Appendix Table A3.

The results of efficiency scores using DEA depend mainly on the input-output variables and the clusters of the water providers in the study. While results of this research results point out that the maximum efficiency can be achieved when the water providers have medium size and employ full prepaid meter system. The study of the Italian water sector showed that public owned water providers have the highest technical efficiency (Lombardi *et al.,* 2019). When comparing 393 water utilities from 11 countries for instance, water utilities from Bangladesh had the best efficiency performance compared to all countries in the study (Senante *et al.,* 2016). Some research showed that high inefficiency in the water sector, such as the efficiency of Indian utilities which were very low especially in the indicators of service provision, service operation, service reliability and financial sustainability. In service provision for instance, the efficiency was below 18.6 % (Gill & Nema, 2016).

The rresults demonstrate that all water providers of different sizes and those who employed prepaid meters; and large size water providers who manage post paid meters or low level of prepaid meters are both set at efficiency frontier line based on variable return to scale. The data analysis explores that the average variable return scale for each level of installed prepaid meter is 0.631, 0.726, 0.738, 0.61, and 0.89 for the zero prepaid, low, medium, high and full prepaid water meter respectively. That implies the higher the level of prepaid meters installed by the water provider to its customers, the higher the average efficiency is achieved, other things being constant.

The findings are in line with the Palestinian water law, which calls for merging water providers into a larger size to reduce costs and increase efficiency. The results also consistent with the PWA which encourages the installation of prepaid meters especially for the water providers who suffer from accumulated debts in order to reduce the debt and increase the service sustainability.

Results of this research guides decision makers in ways that can be followed to increase the efficiency of the water providers based on cost reduction factors, increased revenues and collections, and increased water services to a larger population. The results imply that the efficiency of small-size water providers who employ postpaid meters can be increased by two options: changing all their current meter system to prepaid meter system but keeping their size as is, or increasing their size from small to medium and increasing their level of prepaid meters as well. Empirical results also show that efficiency can be achieved by increasing the percentage of prepaid meters from low to medium, medium to high, while maintaining the same size of service provider; or increasing the water provider size from small to medium. As for the large size water provider, the results reveal that the efficiency can be raised by increasing the level of installed prepaid meters but keeping the size or reduce the size from large to medium and changing all meters to prepaid meters.

Conclusion

With an increase in the installation of prepaid meters in developing countries, there is need to assess the effect of the prepaid meters on the core performance and efficiency of water providers. Cross sectional data from the performance indicators reports were used in this research for more than 100 water providers who were supplying water service to about 80% of the Palestinian population. Multivariate analysis results revealed that there are significant differences in the performance indicators of non-revenue water and deb collection based on the level of prepaid meters roll-out. The correlation analysis showed that there is positive significant relationship between the level of prepaid meters roll-out from the first side, and the average price and collection efficiency from the other side. Negative significant relationship is found between the level of prepaid meters roll-out and the performance indicators of non-revenue water, per capita consumption, financial loss, staff inefficiency and water intermittent in the summer season.

The efficiency scores show that, on average, the Palestinian water providers can reduce the inputs by about 40% without decreasing the outputs. Maximum efficiency can be obtained when the water providers are medium sized and at the same time employing the prepaid meters only.

The research guides decision makers in ways that can be followed to increase the efficiency of the water providers. The efficiency of small-size water providers who employ postpaid meters can be increased by changing their current meter system to prepaid meter system, or increasing their size from small to medium. As for the large size water providers, the results revealed that the efficiency can be raised by increasing the level of installed prepaid meters by keeping the size as it is; or by reducing the size from large to medium and changing all current meters to the prepaid meters.

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Appendices

Table A1: Box's test of equality of covariance matrices[a]

Box's M	27.585
F	1.419
df1	18
df2	3757.631
Sig.	.112

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Prepaid Percentage + Size + Prepaid Percentage * Size

Table A2: Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.687	209.178[b]	2.000	191.000	.000	.687
	Wilks' Lambda	.313	209.178[b]	2.000	191.000	.000	.687
	Hotelling's Trace	2.190	209.178[b]	2.000	191.000	.000	.687
	Roy's Largest Root	2.190	209.178[b]	2.000	191.000	.000	.687
Prepaid Percentage	Pillai's Trace	.077	3.835	4.000	384.000	.005	.038
	Wilks' Lambda	.923	3.877[b]	4.000	382.000	.004	.039
	Hotelling's Trace	.082	3.918	4.000	380.000	.004	.040
	Roy's Largest Root	.078	7.485[c]	2.000	192.000	.001	.072

Table A3: Efficiency scores of each cluster of palestinian water providers

Method			**Input Oriented**				**Output Oriented**			
Firm Features	PP Level	Size	CRSTE	VRSTE	SCALE	RS	CRSTE	VRSTE	SCALE	RS
Level “E”	Zero	Small	0.314	0.415	0.758	irs	0.314	0.325	0.968	irs
Level “E”	Zero	Medium	0.426	0.480	0.887	drs	0.426	0.469	0.656	drs
Level “E”	Zero	Large	0.383	1.000	0.383	drs	0.383	1.000	0.383	drs
Level “D”	Low	Small	0.509	0.655	0.777	irs	0.509	0.561	0.908	irs
Level “D”	Low	Medium	0.521	0.523	0.995	irs	0.521	0.628	0.829	drs
Level “D”	Low	Large	0.487	1.000	0.487	drs	0.487	1.000	0.487	drs
Level “C”	Medium	Small	0.441	0.598	0.737	irs	0.441	0.496	0.889	irs
Level “C”	Medium	Medium	0.630	0.670	0.940	drs	0.630	0.757	0.832	drs
Level “C”	Medium	Large	0.694	0.948	0.732	drs	0.694	0.960	0.723	drs
Level “B”	High	Small	0.386	0.494	0.782	irs	0.386	0.406	0.951	irs
Level “B”	High	Medium	0.704	0.740	0.952	drs	0.704	0.767	0.919	drs
Level “B”	High	Large	0.740	0.912	0.812	drs	0.740	0.943	0.785	drs
Level “A”	Full	Small	0.808	1.000	0.808	irs	0.808	1.000	0.808	irs
Level “A”	Full	Medium	1.000	1.000	1.000	---	1.000	1.000	1.000	---
Level “A”	Full	Large	0.863	1.000	0.863	drs	0.863	1.000	0.863	drs
	Mean		**0.594**	**0.762**	**0.794**		**0.594**	**0.754**	**0.800**	

CRSTE = technical efficiency from CRS DEA, VRSTE = technical efficiency from VRS DEA, SCALE = scale efficiency = CRSTE/VRSTE, irs = increasing return to scale; drs = decreasing return to scale; RS = return to scale.

Table A4: Tests of between-subjects effects

Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	Collection	2.658[a]	7	.380	3.981	.000	.127
	NRW	3976.045[b]	7	568.006	4.307	.000	.136
Intercept	Collection	20.089	1	20.089	210.658	.000	.523
	NRW	18774.512	1	18774.512	142.371	.000	.426
Prepaid Percentage	Collection	.803	2	.402	4.210	.016	.042
	NRW	1279.594	2	639.797	4.852	.009	.048
Size	Collection	.214	2	.107	1.121	.328	.012
	NRW	7.666	2	3.833	.029	.971	.000
Prepaid Percentage * Size	Collection	.319	3	.106	1.116	.344	.017
	NRW	295.816	3	98.605	.748	.525	.012
Error	Collection	18.310	192	.095			
	NRW	25319.150	192	131.871			
Total	Collection	116.990	200				
	NRW	178845.000	200				
Corrected Total	Collection	20.968	199				
	NRW	29295.195	199				

a. R Squared = .127 (Adjusted R Squared = .095)

b. R Squared = .136 (Adjusted R Squared = .104)

Table A5: Correlations matrix

		NRW	Per Capita	Avg. Price	Operating Cost	Collection	Working ratio	Staff productivity	Sumer	Prepaid Percentage
NRW	Pearson Correlation	1	.058	-.178*	.110	-.245**	.325**	.126	-.047	-.309**
	Sig. (2-tailed)		.416	.012	.120	.000	.000	.076	.510	.000
	N	200	200	200	200	200	200	200	200	200
Per Capita	Pearson Correlation	.058	1	-.482**	-.469**	.052	.048	.226**	-.231**	-.235**
	Sig. (2-tailed)	.416		.000	.000	.466	.501	.001	.001	.001
	N	200	200	200	200	200	200	200	200	200
Avg. Price	Pearson Correlation	-.178*	-.482**	1	.664**	.173*	-.417**	-.208**	.286**	.228**
	Sig. (2-tailed)	.012	.000		.000	.014	.000	.003	.000	.001
	N	200	200	200	200	200	200	200	200	200
Operating Cost	Pearson Correlation	.110	-.469**	.664**	1	-.026	.261**	.018	.193**	.081
	Sig. (2-tailed)	.120	.000	.000		.719	.000	.798	.006	.252
	N	200	200	200	200	200	200	200	200	200
Collection	Pearson Correlation	-.245**	.052	.173*	-.026	1	-.274**	-.136	-.055	.331**
	Sig. (2-tailed)	.000	.466	.014	.719		.000	.055	.436	.000
	N	200	200	200	200	200	200	200	200	200
Working ratio	Pearson Correlation	.325**	.048	-.417**	.261**	-.274**	1	.252**	.019	-.243**
	Sig. (2-tailed)	.000	.501	.000	.000	.000		.000	.788	.001
	N	200	200	200	200	200	200	200	200	200
Staff productivity	Pearson Correlation	.126	.226**	-.208**	.018	-.136	.252**	1	.082	-.211**
	Sig. (2-tailed)	.076	.001	.003	.798	.055	.000		.250	.003
	N	200	200	200	200	200	200	200	200	200
Sumer	Pearson Correlation	-.047	-.231**	.286**	.193**	-.055	.019	.082	1	-.140*
	Sig. (2-tailed)	.510	.001	.000	.006	.436	.788	.250		.048
	N	200	200	200	200	200	200	200	200	200
Prepaid Percentage	Pearson Correlation	-.309**	-.235**	.228**	.081	.331**	-.243**	-.211**	-.140*	1
	Sig. (2-tailed)	.000	.001	.001	.252	.000	.001	.003	.048	
	N	200	200	200	200	200	200	200	200	200

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

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