Production cost efficiency analysis of regional water companies in eastern Indonesia

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Abstract. Climate change can cause decreasing the quantity and quality of both surface and groundwater resources due to the increasing temperature and water evaporation. The Regional Water Companies (Perusahaan Daerah Air Minum/PDAMs) that use both surface and groundwater for supplying water to the community have many challenges to expanding services due to the effect of climate change. Also, the territory of Indonesia in the form of an archipelago makes the effect of climate change can be higher and disrupt the stability of water resources, especially in Eastern Indonesia. This study aimed to analyzes the efficiency of production costs by using PDAM performance indicator data for fiscal years 2016 until 2018. The data sourced from the Water Supply Improvement System Implementation Agency (Badan Peningkatan Penyelenggaraan Sistem Penyediaan Air Minum/BPPSPAM). Using a statistical cost method, we highlight several independent variables that are likely to affect PDAM cost-efficiency. The study results showed that of the 48 PDAMs observed, 28 were classified as efficient (58.33%) while the remaining 20 (41.67%) were inefficient. Energy costs, maintenance costs and general administrative costs become significant factors affecting the efficiency of production costs, but not chemical costs. In addition to costs, variable non-revenue water, service coverage and number of employees also influence cost efficiency. An efficient PDAMs can continue to expand their service coverage by reducing non-revenue water and the costs above by also incorporating the impact of climate change in their medium and long-term planning.

1. Background
Climate change affects many aspects of life, one of which is water resources. Global warming could lead to rising temperatures and increased evaporation rates on surface water sources such as rivers, lakes and dams. Increasing the temperature of the earth will lead to a decrease in the quality and quantity of these sources [1]. Also, seawater intrusion and erratic rainfall can worsen both the quality and quantity of raw water. Poor groundwater salinization threatens the presence of water resources in coastal areas [2].

Indonesia is an archipelago that is particularly vulnerable to climate change, especially regarding the high rise in sea levels. It can eliminate the small islands and freshwater sources that exist around the coast. The Eastern region of Indonesia has the characteristics of islands with many small islands being its challenge for the Central and Local Governments in providing primary services, including the provision of decent clean water. Also, Indonesia's poverty concentration is still in eastern Indonesia with the four poorest provinces; (1) Papua 26.64%, (2) West Papua: 21.37%, (3) East Nusa Tenggara 20.90%, (4) Maluku 17.44% and Indonesia average is 9.78% [3]. The geographical challenges in equalization of public services doubled with the challenges of climate change that also hinder the achievement of...
established development goals. Also, the trends in sea surface temperature changes in 1982-2009 found that Pacific Islands in Eastern Indonesia reach the highest sea-level temperature increase trends than other regions [4].

Climate change will disrupt surface water sources such as rivers, lakes, dams, and other springs. The surface water source is the primary source of water distributed by The Water Regional Company (Perusahaan Daerah Air Minum/PDAM) in delivering water to customers, also, to pumped deep well water. PDAM is an essential element of the local government in providing water services. Climate change that attacks this water source will affect terms of PDAM production costs from the outer side, which affects PDAM productivity. The increased use of chemicals for water treatment due to deteriorating water quality and additional energy costs to optimize the distribution of water is a particular concern for PDAMs in addressing the effects of climate change [5]. The addition of these costs will add to the company's burden if there is no proper risk mitigation and adaptation to climate change. Therefore, the efficiency of production costs is vital for how internally PDAM focuses on the efficiency of production costs before expanding to increase the number of customers and the scope of its services [6]. The effect of climate change as an external effect affects how internal PDAMs can expand service coverage by increasing the number of customers.

2. Literature review

2.1. PDAM market and challenge

The performance of all PDAMs in Indonesia in 2018 has not been good with only 58.95% of dams performing "HEALTHY", while the remaining 26.84% and 14.21% performing "UNHEALTHY" and "SICK". Among the problems of PDAMs performance is related to aspects of quality, quantity, and continuity of water supplied as well as non-revenue water that exceeds the standard [7]. PDAM is a local government-owned company that is in the monopolistic business segment because there are not many private companies that partner with PDAM in supplying clean water to the community through the piping system [6]. With advantages and disadvantages in the monopolistic market, PDAM is required to be able to serve customers well and also profit to increase regional revenue. Also, the consequences of monopolistic PDAM are related to tariffs. The determination of tariff by the Local Government also affects the level of full cost recovery. Although the average tariff of PDAM has exceeded the average cost of production nationally, on the other hand, there are 62.40% PDAM that unmeet the cost-recovery due to its tariff and NRW. PDAM's challenge is how synergy, support, and collaboration need to be strengthened to improve health and follow-up improvement of performance indicator levels by stakeholders [7].

2.2. Cost of production and efficiency

In 2018, the average cost of PDAM production nationally was lower than the average rates that indicate that rates set by local governments can already cover production costs [7]. However, the reality is, there are still more than 60% of PDAMs in Indonesia that unmeet the cost recovery. The problem is cost efficiency as well as production-distribution efficiency. The efficiency problems of water supply companies have previously been extensively examined by Wibowo and Alfen [8] in Indonesia, Angeles-Castro et al. [9] in Mexico, as well as Carvalho et al. [10]. The efficiency is related to factors that affect it: the number of customers or the size of the company, non-revenue water, and input-output factors. However, the efficiency of production costs has not been too much, and Muftiadi [6] is limited to one province.

From Muftiadi [6], efficiency can be seen from the value of the efficiency benchmark used as the standard for benchmarking derived from the estimated value calculated from the cost equation obtained from the costs and non-costs variables. This benchmarking is one part to measure how a company is more efficient than a group of companies researched. This benchmarking process uses the statistic cost method used by calculating the average production cost of the company. Then performed a regression analysis to get the most suitable cost curve to be used as a benchmarking standard [11].

2.3. Climate change challenges and water resources
An analysis from Habibie and Nuraini [4] shows that the highest trend changes in Indonesia's rising sea surface temperature in the period 1992-2009 occur in pacific islands in eastern Indonesia. This will have an impact on PDAMs in Eastern Indonesia from this case. The need for adaptation and mitigation of climate change risks despite the underperformance of PDAMs and the task of expanding service coverage will be more onerous [2]. Adaptation should be considered for water quality and better efficiency production costs by integrating additional treatment measures and process control for water supply systems, such as additional costs for chemicals [12]. Because of the decrease in water quality due to the risk of climate change, this is important because it can impact the safety and health of the water that will be consumed by PDAMs customers.

![Figure 1. The impact of climate change on drinking water](image)

### 3. Methodology

#### 3.1. Data source
This study was utilized the performance indicators data of 48 PDAM from 2016 to 2018 which located in Regional IV or eastern Indonesia. The data obtained from BPPSPAM as a regulator in the implementation of drinking water supply.

#### 3.2. Model and analysis
This study uses a modified estimation model from Muftiadi [6] by attributing variable types of costs contained in the details of PDAM performance data. Besides cost, this modification is also included non-cost variables such as service coverage, non-revenue water, and the number of employees. It is intended to be able to measure the extent of productivity of production costs, also, to measure the efficiency of the distribution level and labor in providing water supply to customers.

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\text{APC} = f(\text{CC}, \text{EC}, \text{MC}, \text{GAC}, \text{COVERAGE}, \text{NRW}, \text{EMPLOYEE})
\]

\(i=\text{individual (48 PDAM)}; \quad t=\text{time period (2016-2018)}\)

APC is the average production cost derived from the production cost of PDAM over the last three years. CC is the chemical costs per m$^3$ of water produced, such as chlorine, alum, and other chemicals necessary in the process of water to be drinkable. The greater the cost of chemistry, the more water
quality is expected to be at an inadequate level. EC is the energy costs incurred per m$^3$ in the production process. This cost is the cost of fuel and electricity per m$^3$ to pump from water sources or reservoirs. The greater the cost of fuel, it is suspected that PDAM utilizes deep water wells and basins that are not in high altitude areas. Also, the area of PDAM service is complicated that different elevation levels or hills can affect the energy costs incurred to deliver water with many pumps. The next variable cost is maintenance cost (MC) which is the cost of making repairs for the company’s assets in the form of buildings, machinery, and others. The final cost that can be traced in the general administration cost (GAC), i.e. the cost of office stationery and others. All of the above costs are stated in Rupiah per m$^3$ (IDR/m$^3$).

In addition to variable costs, the above functions also attributed non-cost variables. The non-cost variables included in the above function are three. The first is COVERAGE which is the coverage of the administrative area that comes from the percentage of the number of the served population compared to the number of residents in the administrative area of PDAM is located. The second variable is NRW abbreviated from Non-Revenue Water which is from the percentage of the amount of water sold compared to the amount of water produced and distributed. The last non-cost variable is the number of PDAM employees.

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\text{INEFFICIENT} = 1 < \frac{\text{APC actual}}{\text{APC estimation}} < 1 = \text{EFFICIENT} \]

From this calculation, an estimated APC value is compared to the actual APC value of the average APC value over the past three years. Whether a PDAM is classified as efficient or inefficient is determined by the actual APC and Estimation APC values. A PDAM will be categorized as "efficient" if the actual APC value is lower than the estimated APC. So, PDAM is classified as "inefficient" if the actual APC value is greater than the estimated APC.

### 4. Findings and results

#### 4.1. Descriptive statistics

PDAMs in Eastern Indonesia are classified as Regional IV, consisting of 7 provinces and 52 PDAM evaluated in 2018. Based on performance data from 2016 to 2018, four PDAM lacked data because they were not re-evaluated in the three years, so only 48 PDAM were observed. From the statistics of performance data, a summary was obtained that the average production cost per m$^3$ was IDR 5,129.91. In comparison, the lowest production cost was IDR 788.00 from PDAM Nusa Kenari Alor Regency in East Nusa Tenggara Province. Then, the highest was IDR 13,428.00 from PDAM Tirta Adrian in Nabire regency in Papua Province. The lowest and highest production costs occurred in 2016.

| Variable | Mean | Std. Dev. | Min | Max |
|----------|------|-----------|-----|-----|
| Cost prodcost | 5,129.91 | 2,293.64 | 788.00 | 13,428.00 |
| cc | 31.25 | 78.48 | 0.00 | 687.00 |
| ec | 393.95 | 339.68 | 0.00 | 1,326.00 |
| mc | 219.40 | 140.56 | 0.00 | 760.00 |
| gac | 1,675.50 | 8,688.51 | 274.53 | 7,607.95 |
| Non-Cost coverage | 31.02 | 19.13 | 5.00 | 87.05 |
| nrw | 33.76 | 14.94 | 2.09 | 76.00 |
| employee | 112.47 | 90.38 | 22.00 | 366.00 |
At the cost of chemicals, the average use of chemicals is IDR 31.25 per m$^3$, which is relatively low at 0.61% of the average production cost. It is supported by 30 PDAM that does not use chemicals for water processing. In terms of energy costs, the average energy cost usage is IDR 393.95 per m$^3$. Although the average energy cost is relatively high, reaching 7.68% of the total average production cost, there are still three PDAM that do not use fuel costs in producing water; PDAM Tirta Komodo and PDAM Matawai Amahu in West Nusa Tenggara also PDAM Rote Ndai in East Nusa Tenggara.

Meanwhile, the average maintenance cost is IDR 219.40 per m$^3$. There is only one PDAM that does not exist or does not realize maintenance costs, namely PDAM Gwar Gwammar Kepulauan Aru in 2016. This maintenance cost is very closely related to the piping network assets built by PDAM. While from variable non-cost, the level of administrative coverage of PDAM is at the lowest point of 5.00% in PDAM Tirta Cendana Kabupaten Timor Tengah Utara in East Nusa Tenggara in 2018. This is caused by a significant decrease in customers' numbers, reaching 12.35% from 2017 to 2018. Meanwhile, the average non-revenue water value of all PDAM in East Indonesia is 33.76%, with the lowest NRW value occurring in PDAM Kabupaten Halmahera Selatan at 2.09% in 2017 and the highest in PDAM Kepulauan Morotai in 2018 at 76.00%. The average NRW value of all PDAM in eastern Indonesia exceeds the standard stipulated by 20.00%.

4.2. Estimation result

We estimate the average value of production costs by testing the above cost function equations with three regression models; Common Effect, Random Effect, and Fixed Effect. We tested that the Random Effect Model was the best model among the three. The calculation results found that of the four variable costs, only the cost of chemicals did not have a statistically significant positive effect. Whereas according to [5] and [12] that the addition of chemical and energy costs is one of the adaptation measures of the decrease in water quality and quantity from the impacts of climate change. Energy costs and general administration costs are 99 percent statistically significant, and maintenance costs reach 95 percent significance. These results align with the study [6]. However, the significance of the research in Eastern Indonesia is more significant among West Java.

Table 2. Summary of estimation of average production cost.

| Estimation APC | CEM | FEM | REM$^*$ |
|----------------|-----|-----|--------|
| Constant       | 1,110** (548.0) | 5,158*** (1,717) | 2,300*** (628.5) |
| CC             | 0.987 (1.876) | -0.451 (1.694) | -0.136 (1.597) |
| EC             | 3.241*** (0.432) | 3.169*** (0.971) | 3.447*** (0.548) |
| MC             | 2.653** (1.161) | 1.637 (1.044) | 2.206** (1.001) |
| GAC            | 1.013*** (0.159) | 0.197 (0.148) | 0.490*** (0.138) |
| Coverage       | -27.83*** (8.340) | -3.028 (12.36) | -20.83** (9.268) |
| NRW            | 44.96*** (9.245) | 10.92 (19.81) | 35.79*** (11.64) |
| Employee       | -1.969 (1.875) | -19.80 (12.33) | -3.484 (2.462) |
| F-test         | 27.48 (0.0000) | 1.42 (0.2224) | - |
| BPLM           | 31.73 (0.0000) | | |
| Hausman        | 347.16 (0.0000) | | |
| R-squared      | 0.586 | 0.0360 | 0.5501 |

Notes: Numbers in parentheses are t-statistical values, except for the Breusch-Pagan LM dan Hausman test, which is p-values. Signs *, ** and *** are used to indicate the significance level of 10%, 5%, and 1%.
Table 3. PDAM’s production cost efficiency and ratio.

| Name of PDAM | Province | Actual APC | Estimated APC with REM | Ratio | E/I |
|--------------|----------|------------|------------------------|-------|-----|
| PDAM Nusa Kenari – Kabupaten Alor | East Nusa Tenggara | 961 | 3,845 | 0.25 | E |
| PDAM Tirta Cendana – Timor Tengah Utara | East Nusa Tenggara | 3,000 | 5,187 | 0.58 | E |
| PDAM Kabupaten Lombok Timur | West Nusa Tenggara | 2,721 | 4,224 | 0.64 | E |
| PDAM Kabupaten Timor Tengah Selatan | East Nusa Tenggara | 3,840 | 5,787 | 0.66 | E |
| PDAM Kabupaten Karangasem | Bali | 3,744 | 5,482 | 0.68 | E |
| PDAM Kabupaten Dompu | West Nusa Tenggara | 3,181 | 4,678 | 0.68 | E |
| PDAM Kabupaten Kepulauan Yapen | Papua | 2,510 | 3,611 | 0.70 | E |
| PDAM Kabupaten Klungkung | Bali | 3,877 | 5,378 | 0.72 | E |
| PDAM Kabupaten Bangli | Bali | 5,424 | 7,517 | 0.72 | E |
| PDAM Kabupaten Buleleng | Bali | 3,735 | 5,066 | 0.74 | E |
| PDAM Kabupaten Lombok Utara | West Nusa Tenggara | 2,393 | 3,045 | 0.79 | E |
| PDAM Kabupaten Lembata | East Nusa Tenggara | 3,312 | 4,204 | 0.79 | E |
| PDAM Matawai Amahubu – Sumba Timur | West Nusa Tenggara | 2,979 | 3,723 | 0.80 | E |
| PDAM Kabupaten Halmahera Barat | North Maluku | 3,773 | 4,710 | 0.80 | E |
| PDAM Tirta Kelimutu – Ende | East Nusa Tenggara | 4,769 | 5,797 | 0.82 | E |
| PDAM Kabupaten Maluku Tenggar | Maluku | 5,868 | 7,079 | 0.83 | E |
| PDAM Amertha Jati – Jembrana | Bali | 5,085 | 6,084 | 0.84 | E |
| PDAM Tirta Komodo – Manggarai | West Nusa Tenggara | 3,099 | 3,639 | 0.85 | E |
| PDAM Kabupaten Flores Timur | East Nusa Tenggara | 5,197 | 6,086 | 0.85 | E |
| PDAM Gwar Gwamar – Kepulauan Aru | Maluku | 6,100 | 6,995 | 0.87 | E |
| PDAM Kabupaten Tabanan | Bali | 4,223 | 4,629 | 0.91 | E |
| PERUMDAM Tirta Sajiwani – Gianyar | Bali | 4,697 | 5,163 | 0.91 | E |
| PDAM Kota Ternate | North Maluku | 5,161 | 5,695 | 0.91 | E |
| PDAM Tirta Dharma – Fak-fak | West Papua | 4,596 | 5,020 | 0.92 | E |
| PDAM Kabupaten Sikka | East Nusa Tenggara | 5,724 | 6,177 | 0.93 | E |
| PDAM Kabupaten Buru | Maluku | 7,963 | 8,509 | 0.94 | E |
| PDAM Batulante – Sumbawa | West Nusa Tenggara | 2,792 | 2,906 | 0.96 | E |
| PDAM Kabupaten Halmahera Utara | North Maluku | 6,004 | 6,066 | 0.99 | E |
| PERUMDAM Tirta Sewakadarma – Kota Denpasar | Bali | 4,946 | 4,916 | 1.01 | I |
| PDAM Kabupaten Lombok Tengah | West Nusa Tenggara | 2,611 | 2,548 | 1.02 | I |
| PDAM Rote Ndau | East Nusa Tenggara | 5,851 | 5,744 | 1.02 | I |
| PDAM Kabupaten Manokwari | West Papua | 4,416 | 4,309 | 1.02 | I |
| PDAM Tirta Mangutama Badung | Bali | 7,523 | 7,062 | 1.07 | I |
| PDAM Tirta Lontar - Kapung | East Nusa Tenggara | 7,487 | 6,572 | 1.14 | I |
| PDAM Wae Mbeliling – Manggarai Barat | East Nusa Tenggara | 6,038 | 5,273 | 1.15 | I |
| PDAM Atambua - Belu | East Nusa Tenggara | 7,068 | 6,028 | 1.17 | I |
| PDAM Kabupaten Bima | West Nusa Tenggara | 7,528 | 6,323 | 1.19 | I |
| PDAM Tirta Bening Lontar – Kota Kupang | East Nusa Tenggara | 7,639 | 6,390 | 1.20 | I |
| PDAM Jayapura – Kota Jayapura | Papua | 3,837 | 3,191 | 1.20 | I |
| PDAM Kabupaten Halmahera Selatan | North Maluku | 5,073 | 4,109 | 1.23 | I |
| PDAM Kota Tidore Kepulauan | North Maluku | 10,099 | 8,150 | 1.24 | I |
| PDAM Tirta Yapono – Kota Ambon | Maluku | 8,137 | 6,391 | 1.27 | I |
| PERUMDAM Bintang Bano – Sumbawa Barat | West Nusa Tenggara | 4,723 | 3,683 | 1.28 | I |
| PDAM Tirta Banu – Ngada | East Nusa Tenggara | 5,204 | 3,897 | 1.34 | I |
| PDAM Giri Monang – Kota Mataram | West Nusa Tenggara | 2,929 | 2,131 | 1.37 | I |
| PDAM Kabupaten Kepulauan Morotai | North Maluku | 8,093 | 5,674 | 1.43 | I |
| PDAM Tirta Ina – Maluku Tengah | Maluku | 9,436 | 5,539 | 1.70 | I |
| PDAM Tirta Adrian – Nairin | Papua | 10,870 | 5,953 | 1.83 | I |

Table 4. PDAM’s business plan period.

| PDAM Have a Business Plan? | 2014-2018 | 2015-2019 | 2016-2020 | 2017-2021 | 2017-2022 | 2018-2023 | 2019-2023 | Total |
|---------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-------|
| Yes                       | 6         | 1         | 3         | 1         | 1         | 1         | 2         | 10    | 2      | 1      | 29     |
| No                        |           |           |           |           |           |           |           |       |        |        | 19     |
On all three non-cost variables, two variables are negative: the service coverage and the number of employees. At the same time, the level of non-revenue water has a positive and statistically significant effect. So, the calculation of the estimated cost of average production with the test results using the REM model becomes as follows:

$$\text{APC}_{\text{est}} = 2,300 - 0.136 \text{CC} + 3.447 \text{EC} + 2.206 \text{MC} + 0.490 \text{GAC} - 20.83 \text{Coverage} + 35.79 \text{NRW} - 3.484 \text{Employee} \quad \text{.........(3)}$$

By entering the equation values above and compared to the average actual production cost (Actual APC), the APC estimation results, and the ratio of comparisons between the two are obtained. From the calculation of the ratio, which has an actual ratio per estimate below 1.00, is classified into the "Efficient" PDAM. In contrast, the PDAM, which has the actual ratio per estimate above 1.00, belongs in the "INEFFICIENT." Details of 48 PDAM are presented in the table 3.

From these tables, PDAM which is categorized to be efficient is 28 of the 48 PDAMs. Its shows that PDAM in Eastern Indonesia is still challenging to move swiftly in carrying out efficiency and expanding service coverage. Besides this efficiency, on the planning side, there are only 29 PDAMs with proper business plans until the 2018 financial year. Meanwhile, 19 other PDAMs do not have business plans that can be appropriately owned.

This planning aspect is essential for how PDAMs can carry out action plans in mitigating and adapting to the risks of climate change. Also, to increase the strength of the PDAM in facing the challenges needs support from PDAM stakeholders such as District and Provincial Governments, Ministry of Public Works and Housing, the Association of Indonesian Drinking Water Companies (PERPAMSI), and the Household Community as primary customers.

5. Conclusion
Climate change is a challenge that must be faced by all agencies that are closely related to natural resources, especially for PDAM, as the implementing government agency of water services. From this study, it was concluded that energy costs, general administration costs, and NRW were the main issues for efficiency in PDAMs while the chemical costs to address water quality problems were insignificant. Despite this insignificance, allocating this chemical cost was one of the treatment adaption and process control for safe drinking water supply for PDAMs. All PDAMs must be able to efficiently the production cost first and then adapt and incorporate climate change risks into the business plan, both medium and long term plan.

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