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Dynamic Modelling and Forecasting the Water Price: A Case of Medan, North Sumatera

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ABSTRACT

Water is an important element of life, hence must be preserved. In addition, the pricing of water supply must be consistent and optimal to ensure its sustainability. This paper describes the dynamic model in the forms of mathematical (structural) equations translated from the Regulation of the Minister of Domestic Affairs Indonesia, No. 23 Year 2006. This regulation has been used by Perusahaan Daerah Air Minum (PDAM) Tirtanadi Medan, North Sumatera in determining the water price. The model consists of several economic variables such as minimum wage, inflation, and subsidy that majorly influenced the forecasted water price.

Keywords: Dynamic Model, Water Price, Forecasting, Sustainability.

1. INTRODUCTION

Water is crucial in the life of society, nation and state. A cheaper water price leads to water wastage and is considered an ineffective water management system. The determination of the optimal water price is crucial because it influences the economic system [1].

In this paper, the study is conducted for Perusahaan Daerah Air Minum (PDAM) Tirtanadi Medan, North Sumatera, Indonesia. PDAM is the sole operator and water distributor for more than 2 million people in Medan City, Indonesia. In this study, the Regulation No. 23 of Minister of Domestic Affairs, 2006 is translated into mathematical equations of the dynamic model to prove its correlation with the water law. The regulation serves as the main guideline and had been applied by PDAM Tirtanadi in order to determine the water price. Therefore, the mathematical equations should have accurate correlation and in accordance with the water law for ensuring its transparency and management responsibility.

The role of the dynamic model in solving problem can be well-applied if the problem is known as a clear identification problem. Thus, the dynamic model is formed into the conceptual structure before it can be well-analysed and tested [2]. Sahin *et al*. [3] and Sahin *et al*. [4] presented a system of the dynamic model which augments the usual water utility and representation of the physical linkages of water grids by adding the inter-connected feedback

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loops in the tariff structures, demand levels and financing capacity. Sahin *et al*. [3] and Sahin *et al*. [4] also explained the relationship between the tariff structure, level of demand and the financing capacity based on the feedback.

2. A REVIEW ON OPTIMAL WATER PRICING AND FORECASTING

The optimal price is an essential part of human's life, economy, social and environment. According to Waters [5], the optimal price provides information about product pricing, hence consumers able to avoid counterfeit products. Vasak *et al*. [6] introduced the smart metering application for dynamic pricing within the water distribution system. Furthermore, the optimal water price is considered an appropriate water resource allocation in the dry land area. Hence, it is important for farm management [7].

The optimal water price is a calculation model for water protection, which is carried out to estimate the scarcity water [8]. A study by Mamitimin *et al*. [9] used the multinomial logistic regression, which combined the extensive agricultural land reclamation with unreasonable water usage and it turned into the degradation of ecosystem along the Tarim River. Thus, the optimal water price is considered an effective way to improve water allocation and water conservation.

Optimal water price has an important role in forecasting the water consumption and water distribution system. For example, Lomet *et al*. [10] forecasted the integration of a control strategy in order to optimize the energy cost by heating local water volume. Ju *et al*. [11] study the regression of analysis neural network to forecast the water needs in Mongolia. Chen and Boccelli [12] developed a general purpose Time Series Forecasting Framework (TSFF) to forecast multiple time steps ahead of the water distribution system. Shabani *et al*. [13] proposed a support vector machine model to forecast monthly water demand in the City of Kelowna, Canada. Other forecasting application related to water and hydrology also can be seen in Kamarianakis *et al*. [14].

3. THE OPTIMAL DETERMINATION OF WATER PRICE BASED ON DYNAMIC MODEL

This study has been conducted for Perusahaan Daerah Air Minum (PDAM) Tirtanadi Medan, Sumatera Utara. In this research, the Regulation No. 23 of Domestic Affairs Minister, 2006 is translated into a mathematical equation of dynamic model. Then, the parameter has been analysed using Eviews Version 8.1. So far, the regulation has been applied by PDAM Tirtanadi in order to determine the water price. Therefore, this research will prove the correlation between water price and the regulation mathematically.

From the regulation, the Revenue, R of PDAM, which is affected by the large-small total cost (Tc), the basic rate (Br), low rate (Lr), full rate (Fr), special rate (Sr), and prior period income ($Lag\ R$). Even though if all of the variables that affect the income is included in the model, the economy still cannot be well-predicted due to natural causes and etc. It could be called as disturbance error (mistake), ξ, that incurred into the model. To eliminate the de-trending pattern, the variable of time trend namely t is used as a dummy.

So, revenue is written as:

$$R = \alpha_0 + \alpha_1 Tc + \alpha_2 Br + \alpha_3 Lr + \alpha_4 Fr + \alpha_5 Sr + \alpha_6 lag\ R + \alpha_7 t + \xi_1 \tag{1}$$

*A*ccording to the regulation, *Br* must be less than or equal to 4% provincial minimum wage (PMW). So, the magnitude of *Br* is influenced by the PMW and the inflation. Higher inflation will affect the basic rate, therefore the government used the fiscal policy authority to raise the tax rate. The mathematical equation for *Br* is written as:

$$Br = \beta_0 + \beta_1 PMW + \beta_2 Inf + \beta_3 t + \xi_2 \tag{2}$$

Lr is considered as subsidized recipients and has no returning revenue because no subsidy is given by Indonesia government to PDAM. Furthermore, this rate is only given to certain customer groups. Customer group 1 is divided into two, namely general social group and special social group. Both groups pay lower tariffs than the basic tariffs. The equation can be written as:

$$Lr = \gamma_0 + \gamma_1 Br - \gamma_2 Sub + \gamma_3 t + \xi_3 \tag{3}$$

Fr for customer group 3 subsidizes the low tariff subscribers and generates revenue for PDAM. Therefore, the volume of water sold to full tariff customers must be greater than the volume of water sold at low tariffs. Full rate (progressive rate) should be reasonable and in accordance with the regulation which is equal to 10% of the ratio of earnings to productive assets (RLAP). If the profit is greater than its capital, then the company is healthy. So, *Fr* influenced by RLAP in its mathematical equation is:

$$Fr = \delta_0 + \delta_1 Br + \delta_2 Sub + \delta_3 RLAP + \delta_4 t + \xi_4 \tag{4}$$

The fourth group is the group that pays the largest water tariff which is above the full tariff. This group consists of industries and other commerce. The mathematical equation is written as:

$$Sr = \eta_0 + \eta_1 Fr + \eta_2 t + \xi_5 \tag{5}$$

Tc is the cost used to finance the PDAM Tirtanadi operations. Total cost is influenced by the interest rate on maintenance, investment and purchase input. For the required fund, which is borrowed from the financial institutions was subjected to the interest, *i*. The mathematical equation for the total cost is written as:

$$Tc = \theta_0 - \theta_1 i + \theta_2 t + \xi_6 \tag{6}$$

Cheap water price can increase uncontrolled water usage (wasteful) and costly water pricing will promote efficient water usage but unreasonable to customers. Therefore, it is necessary to determine an optimal water price as an effective policy for the water resources economic and sustainability. According to Chen and Boccelli [12], the government can adjust the pricing parameters in order to control and balance the profit and also control markets' power in order to ensure the public interest and economic benefit. So, the water price can be determined using the mathematical equation shown in Equation (7):

$$P = \lambda_0 + \lambda_1 R + \lambda_2 t + \xi_7 \tag{7}$$

4. DATA PRESENTATION AND STRUCTURAL EQUATIONS

In this section, the data relevant to the mathematical (structural) equations are presented in Table 1, Table 2 and Table 3. Variables that determine the water price such as *P*, *Br*, *Lr*, *Sr* and *Fr* from 2007 until 2016 is presented in Table 1.

Table 1 Variables that determine the price

Year	P (IDR)	Br (IDR)	Lr (IDR)	Sr (IDR)	Fr (IDR)
2007	2,205	1,236	817	4,2007	9,907
2008	2,209	1,238	818	4,2087	9,926
2009	2,224	1,627	851	4,3440	9,961
2010	2,209	1,616	845	4,3152	9,895
2011	2,357	1,724	930	4,6030	10,555
2012	2,418	1,769	1,014	4,7223	10,829
2013	2,782	3,112	1,587	62,240	14,689
2014	3,562	3,393	2,477	67,860	16,015
2015	3,497	3,444	3,134	68,880	16,256
2016	4,137	4,895	3,765	75,300	17,696

Next, the inflation, PMW, interest rate, subsidy and revenue from 2007 to 2016 is shown in Table 2.

Table 2 Inflation, PMW, interest rate, subsidy and revenue from 2007 until 2016

Year	Inflation (%)	PMW	Interest (%)	Subsidy (IDR)	Revenue (IDR 000)
2007	8.71	761,000	12.93	2,005,719,985	247,140,380
2008	12.8	822,205	13.85	1,985,282,968	246,868,157
2009	6.14	905,000	12.56	1,975,064,460	268,625,370
2010	7.65	965,000	10.81	1,929,767,445	284,038,932
2011	3.54	1,035,500	10.34	1,770,952,080	289,077,610
2012	3.79	1,200,000	10.08	1,633,154,125	314,573,969
2013	10.09	1,305,000	10.00	1,701,128,052	374,042,456
2014	6.64	1,505,850	7.25	704,995,906	363,807,353
2015	3.34	1,625,000	6.75	206,929,833	373,633,836
2016	6.34	1,811,875	Not known	Not known	454,323,558

Finally, total cost and RLAP from 2007 until 2016 is presented in Table 3.

Table 3 Total cost and RLAP from 2007 until 2016

Year	Tc (IDR)	RLAP (%)
2007	235,528,280,000	1.9
2008	234,525,468,000	2.2
2009	255,248,069,361	2.5
2010	259,301,323,053	2.7
2011	274,654,312,505	3.1
2012	298,805,001,518	2.4
2013	458,347,182,151	2.5
2014	489,903,023,577	6.5
2015	511,114,803,945	5.6
2016	641,510,998,528	5.1

Then, the price fixed variable is processed using Eviews Version 8.1 and the simultaneous structural equation was obtained by using the annual data. The results from the structural equation are as follows:

$$R = 0.00226Tc - 120020Br - 29283Lr - 184900Fr + 39101Sr + 0.376122Rlag - 114853890t \quad (8)$$
$$Br = 47.75997inf + 381.3919t \quad (9)$$
$$Lr = 0.825999Br - 0.000000212Sub - 16.13908t \quad (10)$$
$$Fr = 2.385347Br + 0.00000210Sub + 850.4251RLAP - 156.1578 \quad (11)$$
$$Sr = 4.283879Fr - 24.82237t \quad (12)$$
$$Tc = 7{,}520000000i + 5{,}2700000000 \quad (13)$$
$$P = 0.00000785R + 43.17942t \quad (14)$$

From Equation (8), *Br*, *Lr* and *Fr* has been marked as negative and not significant as it indicates the presence of the collinearity symptom. This symptom caused many negative and regression coefficients are not significant. To resolve the symptom, economists do some treatments, such as removing the opposing theory, reproduce the observation data and add another variable that affects the dependent variable.

The colony is produced by several independent variables, which are correlated as *Lr*, *Br* and *Fr*. It has a linear relationship on each other because *Lr* and *Fr* are retrieved from *Br* (The Regulation of Domestic Affair Minister, No. 23, 2006). In this study, the observations data only consists of 10 years of data and according to the terms of the simultaneous equations, the data collection period should be at least 18 years.

After the treatment, then the regression equation is obtained as:

$$R = -0.0006Tc + 100487Br + 1.25RLag - 24123503RLAP \quad (15)$$

Then, the result of the new price regression is retrieved as:

$$P = 0.000013R - 0.00000042Sub \quad (16)$$

Substitution of equation (15) into equation (16) retrieved:

$$P = 0.000013\ (-0.0006Tc + 100487Br + 1.25RLag - 24123503RLAP) - 0.00000042\ Sub$$
$$P = 1.31Br + 0.00002RLag - 313.6RLAP - 0.00Sub \quad (17)$$

From the equation (17) is obtained:

$$\frac{dP}{dBr} = 1.31 \quad (18)$$
$$\frac{dFr}{dBr} = 2.39 \quad (19)$$
$$\frac{dSr}{dFr} = 4.28 \quad (20)$$

A policy is produced based on Equation (18), (19) and (20), which is called the elastic constants of elasticity. When elasticity is greater than 1, the regulation is well translated into the water price.

5. FORECASTING THE WATER PRICE FOR PDAM, MEDAN

Forecasting is an activity to forecast price changes outside the period of the study. The objective of this study is to determine the water price in the future which will lead to a positive impact on the economy. In this paper, the structural equation has to be the best model, before the forecasting itself turns into reality. The best model is needed as a way to check the coefficient (residual square) or R^2. If R^2 approaching 1 and probability is less than 0.05, then the model is said to be the best. Thus, the equations (15) and (16) are the best after a substitution of structural equations. Forecasting is conducted for Scenario I raises the Br by 5% while Scenario II raises the Br by 10%. Br is an exogenous variable which is determined by the company. In Scenario I, if the government raises the set fee by 5% then this will be the price in the future. Therefore, the data must be well organized into the actual data of pre-mortem and post-mortem. Table 4 and Table 5 show pre-mortem and its equivalent post-mortem rate (in Indonesian Rupiah, IDR) respectively.

Table 4 Pre-mortem rate from 2007 until 2016

Year	Lr	Br	Fr	Sr
2007	817	1,236	9,907	42,007
2008	818	1,238	9,926	42,087
2009	851	1,627	9,961	43,440
2010	845	1,616	9,895	43,152
2011	930	1,724	10,555	46,030
2012	1,014	1,769	10,829	47,223
2013	1,587	3,112	14,689	62,240
2014	2,477	3,393	16,015	67,860
2015	3,134	3,444	16,256	68,880
2016	3,765	4,895	17,696	75,300

Table 5 Post-mortem rate from 2008 until 2017

Year	Lr	Br	Fr	Sr
2008	858	1,298	10,402	44,107
2009	859	1,300	10,422	44,191
2010	894	1,708	10,459	45,612
2011	887	1,697	10,390	45,310
2012	977	1,810	11,083	48,332
2013	1,065	1,857	11,370	49,584
2014	1,666	3,268	15,423	65,352
2015	2,601	3,563	16,816	71,253
2016	3,291	3,616	17,069	72,324
2017	3,953	5,140	18,581	79,065

If the set fee basis raised by 5%, then the low rate (post-mortem) would rise to IDR 3, 953; full rate rise to IDR 18, 581; and special rate rise to IDR 79, 065 in the year 2017. If the basis increases by 5%, the price of water for a full-rate subscriber (post mortem) rise to IDR 7, 597 in 2017 and to IDR 11, 056 in 2016 for the special-rate customer as presented in Table 6.

Table 6 Water rate based on pre-mortem (2007-2016) and post-mortem (2008-2017)

Pre-Mortem			Post-Mortem		
Years	Fr	Sr	Year	Fr	Sr
2007	2,205	1,937	2008	4,142	6,079
2008	2,209	1941	2009	4,150	6,090
2009	2,224	1,947	2010	4,171	6,119
2010	2,209	1,934	2011	4,143	6,078
2011	2,357	2,064	2012	4,421	6,484
2012	2,418	2,117	2013	4,535	6,652
2013	2,782	2,872	2014	5,654	8,525
2014	3,562	3,131	2015	6,693	9,824
2015	3,497	3,178	2016	6,675	9,853
2016	4,137	3,460	2017	7,597	11,056

6. CONCLUSION

Cheap water pricing leads to water wastage while expensive water price is not economical for the domestic economy and people. Therefore, water pricing needs to optimally design. In Medan, PDAM determined the water price based on law policy and regulation of the Minister of Domestic Affairs No. 23, 2006 thus, it is vulnerable to inaccurate interpretation and perception. This study translated the regulation mathematically into a dynamic model which is more accurate and understandable. The model shows that minimum wage, inflation, and subsidy as the major economic variables that influenced the forecasted water price. It proves that the Regulation of the Minister of Domestic Affairs No. 23, 2006 reached the elasticity as evidenced from $e > 1$, thus confirming that the regulation is well translated into the water price. This dynamic model of water pricing is considered good because it is in accordance with the results of the data processing. As the determinant variable approaches 1, the probability is less than 5%. Furthermore, the model can be used to forecast the future water price for a maximum of 5 years.

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