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Estimating Urban Water Demand Elasticities using Regression Discontinuity: A Case of Tangerang Regency, Indonesia

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Abstract
We estimate the effect of water tariff adjustment in Tangerang city, Indonesia in November 2014 on monthly water consumption. Due to typical water-block pricing strategy, estimating water demand elasticities are likely to be complex. A unique panel monthly water consumption dataset at consumer level in Tangerang regency covering the period of January 2011–September 2016 is used. Using regression discontinuity framework, we find a 13% average tariff increase reduces 4% household water consumption on average. Further, our estimates suggest the tariff adjustment provides no effects on high-income households, industrial, and commercial consumers. We also find more elastic response of water consumption in short-run period than in long-run.

JEL Classification: L95; R22; R53

Keywords
Water Demand Elasticities — Urban Water — Regression Discontinuity Design — Indonesia

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1. Introduction

Clean water plays important roles in fulfilling human basic needs and the access is one of parameters for the quality of life of society. Some manufacturing activities, like food and beverage producers, also consider water as one of important production inputs. Despite its importance, assess to clean water provision is lacking in Indonesia. By 2015, about 14% of Indonesian had unimproved drinking water source (Patunru, 2015). The level of service is also low since regional water companies (*Perusahaan Daerah Air Minum*/PDAM), which provide piped water service cover a small portion of water provision service (Asian Development Bank/ADB, 2016). The majority of water source comes from unpriced groundwater that is harmful toward environment.

Growing population along with low level of piped water service and excessive groundwater use will worsen the supply-demand gap of fresh water provision at national level. Challenges in fresh water scarcity are likely to be greater in fast-urbanized areas because of fierce competition among economic activities (Lundqvist et al., 2003). Understanding the demand behavior is needed to control the demand, while at the same investment in piped water facilities is also indispensable. Grasping how sensitive the demand for water on its price will enable us to use the price as potential instruments to manage the increasing demand over the time.

In this paper, we estimate the water demand elasticity using monthly water consumption of PT Air Aetra Tangerang consumers in Tangerang Regency, Indonesia. The company is privately owned, and together with the regional water company of Tangerang provide fresh-water service for substantial number of citizens of Tangerang. Our monthly water consumption covers 57 months and more than 50 thousand customers forming about 1.6 million monthly-consumer panel observations. The rich dataset also covers several types of consumers, including household, business, commercial, and social, which enables us to estimate the consumption effect of tariff change across group of consumers.

To obtain the causal impact, we exploit event of unprecedented tariff adjustment in November 2014 as the forcing variable of regression discontinuity framework. The company announced the tariff adjustment without brief announcement in advance. We adopt Luechinger & Roth' (2016) estimation strategy to reduce the estimation bias by controlling consumer fixed-effect, polynomial time trend, and other control variables. Estimated standard errors are clustered to reduce potential bias due to serial correlation (Bertrand et al., 2004; Cameron et al., 2011). In the context of Indonesia, we extend the work of Rietveld et al. (2000) who estimated residential water demand in Solo, Indonesia to obtain non-residential water demand elasticity as well as distinguish between short-run and long-run estimates.

This study is also of international interest in that, typical water demand elasticity estimations are potentially biased because of complex structure of water service tariff schemes and whether consumers fully aware with the schemes (Nataraj & Hanemann, 2011). We use regression discontinuity with time as forcing variable to minimize the estimation biases, exploiting the fact that the percentage change in tariff is relatively homogenous across blocks and

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Figure 1. Map of Tangerang Regency and Sub-districts served by PT Aetra Air Tangerang
Note: grey areas indicate subdistricts served by PT Aetra Air Tangerang
Source: Direct correspondence with PT Aetra Air Tangerang (Geospatial Information Board, 2017)

consumer groups.

Our paper proceeds as follows. Section 2 explains current system of water provision in the Tangerang Regency and how PT Aetra contributes in the system. Section 3 describes our model and data, and discusses the expected effects of sudden tariff adjustment on water consumption. Section 4 provides discussion on the estimation results. Final section concludes.

2. Context: Water Utility Provision and Position of PT Aetra Air Tangerang in Tangerang Regency

Tangerang regency is situated in the Java island, the province of Banten, and 40 kilometers away to the west side of Jakarta, the capital city of Indonesia. The regency is part of greater metropolitan area, known as Jabodetabeka one of the world's largest urbanized areas. By 2016, there were about 823 thousand households living in Tangerang regency, spreading in 29 sub-districts. Most households are living in Pasar Kemis sub-district, while the least households are in Mekarbaru sub-district.

As commonly practiced in Indonesia, water provision for household and non-household activities in Tangerang regency mainly come from piped water provided by a regional water company (PDAM Tirta Kerta Raharja), or from ground water, river, and other natural source of water. In some areas, private companies enter the market to provide the service. To extent the coverage of piped water provision, the local government of Tangerang regency invited private company by 2008, i.e. PT Aetra Air Tangerang, to serve the drinking water service in eight sub-districts over 25 years of concession. The eight sub-districts include Sepatan, Sepatan Timur, Pasar Kemis, Cikupa, Sindang Jaya, Sukamulya, Balaraja, and Jayanti using the water source from Cisadane river (*see Figure 1*). The company is designed to cover about 72.000 households, equivalent of 350.000 inhabitants, and non-household connections. Meanwhile, other sub-districts are served by PDAM of Tangerang regency.

Table 1 provides a recent tariff scheme as of March 2017. PT Aetra Air Tangerang imposes block pricing tariff; the higher water consumed, the higher per m^3 water tariff to be paid. The tariff is also differentiated across consumers. Households, as the main consumer, are divided into four groups based on assets that primarily surveyed before they subscribed into the service. Households with least asset will fall into R1 group and be charged with subsidized tariff. The highest is borne by R4 group which owns most assets. Non-household costumers are differentiated in similar fashion. Social consumers, such as mosques and orphanages are subsidized. Other groups include government, commercial, and industrial use are charged much higher than the social group.

The tariff system is, however, strictly regulated by the government. At national level, Minister of Home Affairs Regulation No. 71 year 2016 on the Calculation and Determination of Drinking Water Tariffs stipulates the maximum level of water tariff such that the cost borne by household for first 10 m^3 consumption should not exceed 4% of Provincial minimum wage income. The company also cannot increase the tariff except there is approval from the mayor. Any change in tariff must be at least 2 years after the latest tariff adjustment. By far, the company has adjusted the tariff twice, by October 2014 and March 2017. The first tariff adjustment was more sudden and less anticipated by customers as the company announced the change after the new tariff was imposed. The last adjustment was potentially more anticipated as the plan had been socialized beforehand.

3. Method

Basic Model and Data We are interested in estimating the impacts of the October 2014 water tariff adjustment on monthly water consumption. To obtain the causal relationship, we use regression discontinuity with time variable as assignment variable (Auffhammer & Kellogg, 2011; Chen & Whalley, 2012; Luechinger & Roth, 2016). This approach

Table 1. Water Tariff Regime by Consumer Type by March 2017

Consumer type	Tariff scheme (Rupiah/m^3)		
	<10 m^3	10–20 m^3	>20 m^3
Social	1450	1450	1450
Government	10280	10280	10280
Household			
R1	2170	2170	2170
R2	4530	5350	6440
R3	7420	8905	10415
R4	10400	12010	13450
Commercial	13300	14700	16100
Industry	16726	16726	16726

Source: *Keputusan* Bupati Tangerang 690/Kep.206.Huk/2017

identifies the effect of the policy by examining the discontinuous variation around the known cutoff (Jales & Yu, 2017), in our case is the month of new tariff implemented. The estimation can be written as:

$$\ln(y_{it}+1) = \alpha_i + \beta D_t + \mathbf{X}'\gamma + \theta f(t) + e_{it} \qquad (1)$$

The dependent variable is monthly water consumption of consumer i in month t, presented in natural logarithm. The consumption is added by one to avoid dropped observation under logarithm transformation. Water consumption is from metered monthly water consumption data of PT Aetra Air Tangerang customers recorded from January 2012 to September 2016, or for 57 months. With a total customer base of 55.7 thousand subscribers, there are more than 3.2 million potential observations. However, as some customers have not subscribed since January 2012, it may cause missing observations, thus about 1.7 million observations can be used in the model.

Our variable of interest is dummy variable D_t, that capture policy change in tariff of water. The value is 1 for the period after the new tariff is applied, and 0, otherwise. We assume that the effect of change in price has started from November 2014 as PT. Aetra Air Tangerang announced the policy by mid-October 2014. Percent change in water consumption due to change in the water price is then calculated as $100(e^{\beta}-1)$ (Wooldridge, 2010). The elasticity of each consumer group k, ε^k, is then calculated by dividing the percent change in water consumption by the percent change in water price for respective group, θ^k, such that $\varepsilon^k = \frac{100(e^{\beta}-1)}{\theta^k}$.

Table 2 presents the water tariff regime by consumer type, before and after October 2014's tariff adjustment. Tariff is discriminated by consumer groups and consumption size under cross-subsidy spirit. Consumers are divided into household and non-household consumers. Household consumers are further divided into four groups, based on their assets and/or land size. Per m^3 tariff is higher for higher household type, where R1 pays subsidized tariff. Non-consumer groups consist of subsidized social, government, commercial, and industrial consumers.

By October 2014, PT Aetra applied sudden adjustment in tariff. Consumers, on average pay 13–15% higher tariff, except social and R1 household consumers. The company can adjust the tariff at least biannually and must be consulted by the major. The adjustment must follow the principle of affordability and fairness. According to Minister of Home Affairs Regulation No. 71/2016 on the Drinking Water Tariffs Calculation, household expenditure to fulfil drinking water standards of basic needs (10 m^3) should not exceed 4% of Banten's Provincial Minimum Wage. For example, the minimum wage of Banten Province is Rp3.021,650 by 2016, as stipulated in the Decree of the Governor of Banten, No. 561/Kep-Huk/2016. concerning the determination of the minimum wage of Banten Province, the drinking water tariff should not exceed more than Rp71.360 in the event of a tariff increase.

Our strategy to estimate the price elasticity relies on assumption that discontinuous price scheme changed at October 2014 is the only factor captured by variable D_t. To ensure this assumption, Equation (1) contains observable control variables in $\mathbf{X}'$ and relies on polynomial order to reduce the bias from unobservable factors.

$\mathbf{X}'$ in Equation (1) is a vector containing list of control variables. We control for monthly GDP, which serves as income variable. The variable is proxied by quarterly GDP data and industrial production index. Our set of variables also include monthly precipitation at village level to control activities which need water use, such as garden watering. Impact from tariff change is also controlled through monthly consumer price index. We also introduce dummy variables for Idul Fithri celebration, which is held following lunar calendar. We include dummy for drought in Cisadane river, which is served as source of Aetra's water, in August 2015. Our dummies also include month-of-year and year dummies to capture seasonality and different long-term trend, respectively. Detail explanation and source of data are presented in Appendix A.

Due to data limitation at individual level, the model cannot control unobservable individual factors that potentially affect water consumption, such as number of household members, that may change during our data period. We use consumer fixed-effect panel estimation to eliminate omitted variable bias from unobserved time-invariant variables. Additionally, many other unobserved variables, which vary over time, are not included into the model. Therefore, we introduce polynomial time trend, $f(t)$, to reduce the bias (Luechinger & Roth, 2016). We later perform a robustness test of polynomial order to check in what extent our elasticity estimates remain robust for the higher order.

Water consumption is unlikely to be independent across time. In addition, our dataset involves relatively long series, i.e. 57 months. Both factors potentially create serial correlation problem (Bertrand et al., 2004). Hence, we allow unobserved disturbance e_{it} to be correlated within same consumer and year, following Cameron et al.'s (2011) procedure to capture within-consumer correlation and serial

Table 2. Water Tariff Regime by Consumer Type

Consumer type	Tariff scheme (Rupiah/m^3)								
	Before October 2014			After October 2014, before March 2017			Percent change		
	0–10 m^3	10–20 m^3	>20 m^3	0–10 m^3	10–20 m^3	>20 m^3	0–10 m^3	10–20 m^3	>20 m^3
Social	1.250	1.550	1.825	1.325	1.650	1.950	6.0	6.5	6.9
Government	8.100	8.100	8.100	9.175	9.175	9.175	13.3	13.3	13.3
Household									
R1	1.900	1.900	1.900	2.025	2.025	2.025	6.6	6.6	6.6
R2	3.575	4.150	5.000	4.045	4.775	5.750	13.2	15.1	15.0
R3	5.850	6.950	8.100	6.625	7.950	9.300	13.2	14.4	14.8
R4	8.125	9.250	10.375	9.200	10.625	11.900	13.2	14.9	14.7
Commercial	10.325	11.450	12.575	11.675	12.900	14.200	13.1	12.7	12.9
Industry	13.216	13.216	13.216	14.934	14.934	14.934	13.0	13.0	13.0

Source: PT Aetra Air Tangerang (http://aat.co.id/informasi-rate/ retrieved at 2016)

correlation problem.The reported standard errors are then clustered on each consumer-year combination.

The estimates will also suffer parameter bias if the consumers can anticipate the policy by adjusting their behavior before the new tariff announced (see Lee & Lemieux, 2010). The response parameter is potentially underestimated if consumers may alter their water consumption behavior before the tariff adjustment was announced. In our setting, the bias can be, however, reduced as PT Aetra Air Tangerang announced the new tariff once it was effectively implemented[1].

Our dataset captures all PT Aetra Air Tangerang's consumers, not only households, but non-households as well. This enables us to estimate Equation (1) for each consumer groups and compares the response across groups.

3.1 Short-run Response

We are also interested in examining whether the response differs across time frame. Demand can be more elastic or inelastic, depending on the nature of goods, in the short-run. To obtain the response of the first n-month, we modify an asymmetric model, which divides independent variable of interest into two states (York, 2012; Burke et al., 2015). In short, we estimate:

$$\ln(y_{it}+1) = \alpha_i + \beta_1 D_t^1 + \beta_2 D_t^2 + \mathbf{X}'\gamma + \theta f(t) + e_{it} \quad (2)$$

where D_t^1 is dummy variable taking values equals one for first several months after tariff increase and zero, otherwise. Meanwhile dummy D_t^2 is assigned as zero for before tariff increase and first several months in D_t^1, and one, otherwise. This setting allows us to separate the average effect for the first several months (β_1) and the effect thereafter (β_2). We estimate Equation (2) for first two until twelve months after the tariff increase.

3.2 Expected Response of the Water Tariff Adjustment

What is the impact of water tariff increase on monthly water consumption of PT Aetra Air Tangerang customers? The basic economic theory of demand states that tariff increase induces the water consumption reduction. The percentage reduction, nevertheless, is expected to be relatively smaller than the percentage tariff increase as water is basic need.

There are reasons, however, to assume that the response may differ across consumer groups. According to empirical study by Yoo et al. (2014) in Arizona, high-income households tend to respond less than low-income households do. Further, we expect non-household groups, particularly industrial and commercial consumers to be less responsive toward tariff adjustment as they have less options for PT Aetra's water source substitution. Similarly, we expect that the short-run response is different from the longer-run response.

To have better understanding of the behavior water consumption near the tariff adjustment, Figure 1 illustrates the average monthly water consumption from our raw data for household and non-household costumers. The graphs plot average monthly of household's water consumption against the month-distance to November 2014. To get better visualization, we add a simple regression of the consumption as a polynomial function of time. First, we focus on household consumer as it accounts for more than 90% of Aetra's total consumers. There is a positive trend in household's water consumption. Further, the regression lines suggest a drop of household's water consumption after November 2014. Substantial drop in water consumption after November 2014 is also evident for non-household costumers. This result gives an initial evidence of the adverse effect of tariff adjustment on the water consumption. The subsequent section provides the empirical evidence of such effect.

4. Results

4.1 Regression estimates

Table presents our panel data estimates of Equation (1). To control high heterogeneity between group, the result is divided into two groups, household and non-household. First column of each groups represents the estimate using all samples. For the evidence on potential heterogeneity, we then disaggregate two subsamples. Household consumers are divided into R2 and R3–R4 household consumers. Non-household subsamples comprise of commercial-industrial and social consumers. We exclude R1 households and government consumers as their number of consumers is relatively low.

The result suggests that the price elasticity varies across subcategories. For household consumers, the water consumption drops 5.0% on average, statistically different from zero at 1% level of significance. This result is, however, driven by the R2 household as more than 90% of consumers falls in this group. Given 14.4% tariff increase for R2 household, the water price elasticity of R2 household is -0.35. If R3 and R4 groups response is estimated separately, the water consumption drops by 5.6%, yet statistically not different from zero. The estimates nevertheless suggest that

[1] We obtain this information from direct correspondence with PT Aetra.

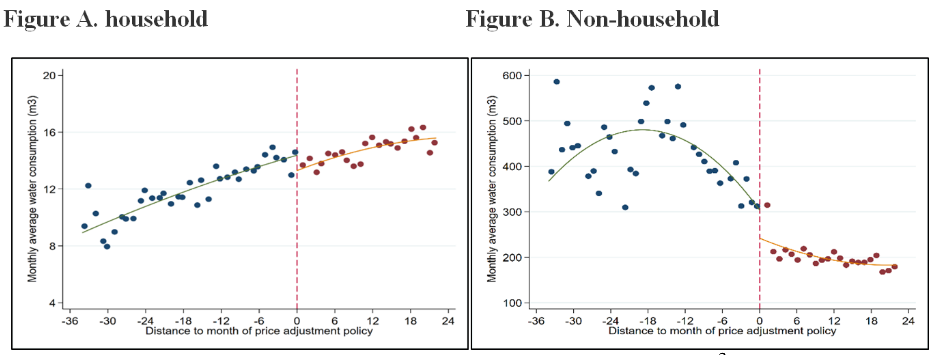

Figure 2. Average Monthly Water Consumption (m^3)
Note: red vertical line indicates starting month of new tariff was introduced in November 2014.
Blue and red dots represent monthly average water consumption, respectively, measured in m^3.
Blue lines are the fitted curves

Table 3. Impacts of Tariff Adjustment on Monthly Water Consumption: Base Results

	Household			Non-household		
	All sample	R2	R3–R4	All sample	Commercial & Industrial	Social
Tariff adjustment	-0.0510*	-0.0505*	-0.0578	-0.0401	-0.00824	-0.0755
(November 2014)	(0.007)	(0.007)	(0.037)	(0.070)	(0.088)	(0.117)
Month-of-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Consumer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic Polynomial time trend	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
# Consumers	52.596	50.243	2.454	2.160	1.808	248
# Observations	1,681,917	1,604,295	81,254	49,27	38,609	7,002
Within-R^2	0.0613	0.065	0.0187	0.0319	0.0345	0.093
Water demand elasticity	-0.38*	-0.38*	-0.43	-0.30	-0.06	-0.56

Note: *, **, *** indicate statistical significance at 1, 5, and 10%, respectively.
Clustered Standard errors are reported in parentheses and clustered at consumer-year level.
The within-R^2 calculates the explanatory power of the time-varying explanatory variables.
Price increase is dummy variable, which value is 1 after October 2014, and 0 otherwise.
Additional control variables include monthly GDP, monthly precipitation, consumer price index, dummy year, dummy Idul Fithri, and dummy drought.
Detail explanation of additional control variables is in Appendix A.

our result is consistent with recent literature on water price elasticity (for example, see Yoo et al., 2014).

Estimates in Table 3 also suggest that non-household consumers are relatively not responsive toward tariff adjustment. Tariff adjustment drops the water consumption by 3.0%, yet is not different from zero. Similar result is also found for the subcategories: social, and commercial and industrial consumers.

Our table estimates do not provide coefficients for control variables. In this section, we provide a discussion of these coefficients. Water consumptions tend to increase by around 1–3% when precipitation rate increases by one percent. We also find GDP elasticity of water consumptions of 0.3–0.6% for household consumers, statistically different from zero at 1%. The GDP elasticity is, however, not different from zero for non-household consumers. We find positive and significant effects of Idul Fithri holiday period, as well as drought in August 2016. Water consumption is seasonal, with the lowest monthly consumptions tending in August and the highest in November, ceteris paribus.

Aside from heterogeneity across consumers, there might be considerable regional variation in the elasticity. Table 4 provides the result for three sub-districts with highest number of customers, i.e. Pasar Kemis, Sepatan, and Cikupa. The estimates are drawn from interacting the intervening variable and dummy sub-districts. We find substantial variation of response in the monthly average water consumption. The elasticity of two sub-districts, Pasar Kemis and Sepatan, is higher than our baseline estimates of -0.38. There are variety reasons that can result in this spatial response. Some sub-districts are relatively easier to find the alternative cheaper water sources, for example ground water, so that the change in tariff has elastic impact. In contrast, there might be sub-districts inhabited by substantial number of new consumers, for which PT Aetra Air Tangerang offered a flat tariff over certain period, and hence are not affected by the tariff adjustment.

4.2 Short-run Response

We now examine the short-run response of tariff adjustment. The estimates are divided for household and non-household consumers. Figure 2 presents the first n-month price elasticity. From Panel A, we find that the point estimates of elasticity are ranging from -0.26 to -0.45, relatively similar with our household's estimate in the table 4, and statistically different from zero at 1% level of significance. Nevertheless, the magnitude tends to be slightly less elastic for longer month. Household consumer adjust their water consumption more during first several months, yet the effect is less in the longer-run period.

In Panel B, the short-run response for the non-household consumer is within the region of –(0.75–0.00) and all point

Table 4. Heterogeneity Across Subdistrict

	Household		
	(1)	(2)	(3)
Tariff adjustment (November 2014)	-0.0227* (0.006)	-0.0390* (0.006)	-0.0576* (0.006)
*Pasar Kemis	-0.0572* (0.005)		
*Sepatan		-0.102* (0.006)	
*Cikupa			0.0259* (0.005)
Month-of-year dummies	Yes	Yes	Yes
Consumer fixed effects	Yes	Yes	Yes
Quadratic Polynomial time trend	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes
# Consumers		52,596	
# Observations		1,681,917	
Within-R^2	0.0617	0.0619	0.0614
Water demand elasticity	-0.53*	-0.91*	-0.17*

Note: *, **, *** indicate statistical significance at 1, 5, and 10%, respectively. Standard errors are reported in parentheses and clustered at consumer-year level. The within-R^2 calculates the explanatory power of the time-varying explanatory variables. Price increase is dummy variable, which value is 1 after October 2014, and 0 otherwise. Additional control variables include monthly GDP, monthly precipitation, consumer price index, dummy year, dummy Idul Fithri, and dummy drought. Detail explanation of additional control variables is in Appendix A.

estimates are not statistically not different from zero at 5% level of significance. Focusing on the point estimates alone, the magnitude is rather more elastic for longer-run period.

4.3 Testing the Robustness

We follow Luechinger & Roth (2016) in performing our robustness test of our model to changes in time polynomial order. The check is done for both household and non-household consumer. Table 5 presents the estimation result up to fourth time polynomial order. Columns 1–4 are for household estimates, and the rest is for non-household estimates.

The estimates are, in general robust in both, sign and magnitude. Except for the linear order, the estimates are within –(0.051–0.057) and –(0.040–0.045) for household and non-household consumer, respectively. Additionally, all estimates are statistically significant at 1% level for household consumer, consistent with the base estimates in main result. Similar result is also found for non-household consumer: all estimates are statistically insignificant.

Our robustness check provides, however, less intuitive result for higher polynomial order. Both magnitude and statistical significance substantially change as the order gets higher, as presented in the Appendix. This indicates that estimates are substantially affected by the higher polynomial order (Luechinger & Roth, 2016). We guess that our time frame, which is relatively much shorter than other similar regression-discontinuity studies is partially responsible for inconsistent estimates for higher order.

To further check the robustness of the estimates, we use falsification tests by shifting the tariff adjustment one and to year backward to October 2013 and 2012, respectively. Table 6 reports the results for household and non-household consumers. The estimates become positive and statistically significant for household consumers, which are less intuitive. Meanwhile, the estimates for non-household consumers are negative and statistically not different from zero.

5. Discussion

In this paper, we have estimated water demand elasticities using unprecedented tariff adjustment event in Tangerang regency, Indonesia. We used regression discontinuity framework using time as forcing variable to elicit the casual impact between the tariff change and monthly water consumption. This approach avoids us from the endogeneity problem or estimation complexity if average or marginal price is used, respectively. The estimates are relatively robust. The robustness check by time polynomial also shows the estimated elasticities are mostly consistent to be less than unity or statistically not different from zero.

Our estimates results show that monthly water demand elasticities of PT Aetra Air Tangerang household consumers in Tangerang regency of Indonesia is -0.38 on average. Higher-income tends to be not sensitive toward tariff adjustment policy. This result confirms recent international evidence that the elasticities are likely to be less than zero. Specifically, the results are within overview of the estimates for developing countries by Nauges & Whittington (2009), which lie in the range from -0.3 to -0.6. Our estimates are also close with Dalhuisen et al.'s (2003) meta-analysis of price elasticities of water demand between 80's and 90's. For similar estimates in Indonesia, our estimates are much lower than Rietveld et al.'s (2000) elastic estimates for Solo, Indonesia. Table 7 summarizes selected prior estimates of water demand elasticity. For household consumers, our estimates are relatively comparable with other similar studies. The estimates are slightly higher than Nataraj & Hane-

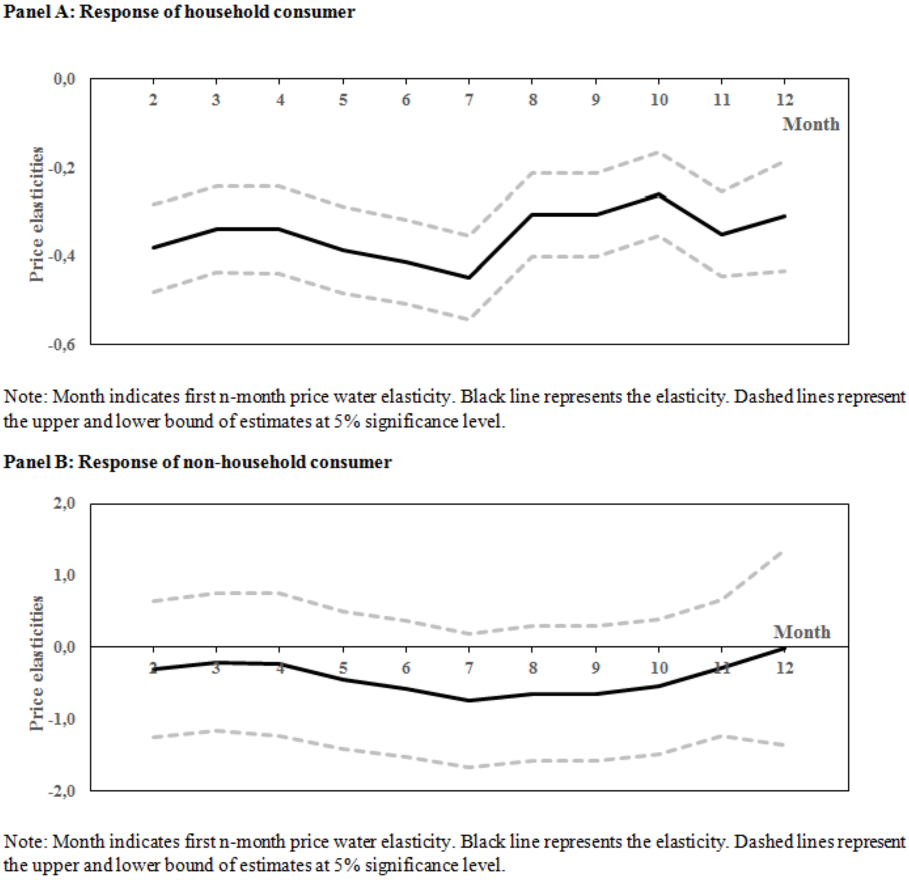

Figure 3. Monthly Short-run Response

mann's (2011) estimates of -0.12 for Santa Cruz, California, Mansur & Olmstead's (2012) of -0.33 for 11 North American cities, Polycarpou & Zachariadis' (2013) of -0.25 for Cyprus, and Strong & Goemans' (2015) estimates of -0.23 for Aurora, Colorado. Our estimates are relatively comparable with Martínez-Espiñeira's (2007) for Spain. Yoo et al. (2014) reported much elastic result for the case of Phoenix, Arizona. In addition, our short-run estimates are slightly higher than the long-run estimates, despite remaining inelastic. Martínez-Espiñeira (2007) used error-correction model to distinguish short-run and long-run water demand elasticity for Spain and found that his short-run estimates are more inelastic than the long-run estimates.

We also found that non-household consumers are not sensitive toward the tariff adjustment. Meanwhile, we find no statistical difference of response across time for non-household consumers. Yet, our short-run estimates for non-household consumers are relatively lower than Shen & Lin's (2017) estimates of -0.12 for agricultural water demand in China or Davidson & Hellegers' (2011) estimates of -0.44 for irrigation water in Musi, India.

Our estimates of water demand elasticity could be used to parameterize the aggregate demand for water and thus to project the water demand-supply balance in the future. ADB (2016) reported that current local government own water utilities only cover 30–40% of the service area and the trend in gap is widening. Given the estimated elasticities, the government may formulate pricing strategies for water utilities to manage the demand, while at the same time expand the service.

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Table 5. Robustness Check: Results Under Different Polynomial Order

	Household				Non-Household			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Tariff adjustment (November 2014)	-0.103* (0.006)	-0.051* (0.007)	-0.057* (0.007)	-0.055* (0.007)	-0.195* (0.065)	-0.040 (0.070)	-0.041 (0.071)	-0.045 (0.071)
Month-of-year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Consumer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quartic Polynomial time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Consumers	52.596				2.160			
# Observations	1.681,92				49.270			
Within-R^2	0.061	0.061	0.061	0.061	0.030	0.032	0.032	0.032
Water demand elasticity	-0.75*	-0.38*	-0.42*	-0.41*	-1.36*	-0.30	-0.31	-0.34

Note: *, **, *** indicate statistical significance at 1, 5, and 10%, respectively.
Standard errors are reported in parentheses and clustered at consumer-year level.
The within-R^2 calculates the explanatory power of the time-varying explanatory variables.
Price increase is dummy variable, which value is 1 after October 2014, and 0 otherwise.
Additional control variables include monthly GDP, monthly precipitation, consumer price index, dummy year, dummy Idul Fithri, and dummy drought.
Detail explanation of additional control variables is in Appendix A.

Table 6. Falsification Tests: Shifting the Date of Tariff Intervention

	Household		Non-Household	
	October 2013	October 2012	October 2013	October 2012
Tariff increase	0.00927** (0.005)	0.0243* (0.008)	-0.0514 (0.058)	-0.145 (0.119)
Month-of-year dummies	Yes	Yes	Yes	Yes
Consumer fixed effects	Yes	Yes	Yes	Yes
Quadratic Polynomial time trend	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes
# Consumers	52,596	52,596	2,16	2,16
# Observations	1,681,917	1,681,917	49,27	49,27
Within-R^2	0.00869	0.0087	0.026	0.026

Note: *, **, *** indicate statistical significance at 1, 5, and 10%, respectively.
Standard errors are reported in parentheses and clustered at consumer-year level.
The within-R^2 calculates the explanatory power of the time-varying explanatory variables.
Price increase is dummy variable, which value is 1 after October 2014, and 0 otherwise.
Additional control variables include monthly GDP, monthly precipitation, consumer price index, dummy year, dummy Idul Fithri, and dummy drought.
Detail explanation of additional control variables is in Appendix A.

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Table 7. Summary of Selected Prior Estimates of Water Demand Elasticity

Study	Country	Price elasticity of water demand		Note
		Short-run	Long-run	
Hewitt and Hanemann (1995)	US		-1.60	Residential
Rietveld et al. (2000)	Indonesia		-1.20	Residential
Martinez-Espiñeira (2002)	Spain	-0.12		Residential
Martinez-Espineira (2007)	Spain	-0.10	-0.50	Residential
Davidson and Hellegers (2011)	India		-0.44	Irrigation
Nataraj and Hanemann (2011)	US		-0.12	Residential
Strong and Goemans (2015)	US		-0.23	Residential
Polycarpou and Zachariadis (2013)	Cyprus		-0.25	Residential
Yoo et al. (2014)	US		-0.90	Residential
Shen and Lin (2017)	China	-0.12		Agricultural

Note: Studies are ordered chronologically.
The list is sample studies only.
Definition of short-run and long-run may differ across studies.

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Appendix A: Variable Definitions

Water consumption: Number of monthly water consumption in m^3. Source: direct correspondence with PT Aetra Air Tangerang.

GDP: monthly gross domestic product. The data is available at quarterly and yearly basis. We follow Burke et al. (2017) approach to construct the variable by weighting the yearly GDP by that month's industrial production index relative to other months in respective year. The formula is:

$$GDP_m = GDP_y * \frac{IndustrialProductionIndex_m}{\sum_{1^{st} monthofyear}^{12^{nd} monthofyear} IndustrialProductionIndex_i} \quad \text{(A1)}$$

Source: Badan Pusat Statistik (2017a,b) and CEIC (2017)

Precipitation: area-averaged monthly precipitation at village level, measured in millimeters. Source: National Aeronautics and Space Administration/NASA (2017), series TRMM_3B43.

CPI: monthly national average consumer price index. Source: Badan Pusat Statistik (2017c)

Idul Fithri: dummy variable that takes 1 if a respective month contains Idul Fithri holidays, and 0 otherwise. Source: www.timeanddate.com

Following Idul Fithri: dummy variable that takes 1 for months after the Idul Fithri holidays, and zero otherwise. Source: Source: www.timeanddate.com

Drought: dummy variable representing drought event in Cisadane river, the main supplying raw water for PT Aetra Air Tangerang, at August 2015. The variable takes 1 for August 2015, and 0 otherwise. Source: direct correspondence with PT Aetra Air Tangerang.

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