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Estimation of The Price and Income Elasticities of Residential Electricity Demand in Indonesia Using Household-Level Data

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Abstract

This paper presents household-level econometric estimates of income and price elasticities of residential electricity demand in Indonesia. Using annual household survey panel data of SUSENAS from 2011 to 2013, the estimation controls for household characteristics that significantly affect electricity consumption, such as demographic aspects, house size, and ownership of home appliances. The empirical results showed that in Indonesia, the residential electricity is price- and income-inelastic, with price and income elasticities of -0.88 and 0.3, respectively. Urban residents use more electricity than rural residents. Responding to economic growth , the government should prepare greater electricity capacity or induce higher tariffs to encourage electricity savings.

Keywords: household data, electricity demand, price elasticity, income elasticity

JEL Classification: C13, C22, D12, Q41

INTRODUCTION

The present paper uses a single equation approach to estimate the price and income elasticities residential electricity demand in Indonesia. This paper postulates that the residential demand for electricity depends not only on the price of electricity and income levels but also on demographic characteristics, ownership of household appliances, and dwelling size. The residential electricity consumption may also be affected by geographical location, urban or rural. We study the sensitivity of price, income, and other household characteristics to electricity demand using an annual panel household-level data for three years of observation from 2011 to 2013.

Several studies on the electricity demand in Indonesia used aggregate data. For instance, Burke and Kurniawati (2018) employed a three-dimensional dataset covering 6 consumer groups, 16 regions and 23 years of observations to calculate the demand-side effects of Indonesia's electricity subsidy reforms on electricity use. In the residential electricity topic, Arnaz (2018) applied a double-log demand equation on PLN electricity sales of the entire groups and residential consumer group. Aggregate data are widely available containing electricity usage over long periods of time. However, aggregate data do not contain specific information on household behavioural factors.

Studies on micro-level data provide flexibility to understand more about the decision and behaviour of consumers. The micro-level studies include household characteristics such as the number of household members, education level, and age profile. These characteristics could reduce estimation biases when understanding energy demand changes in the residential sector. The micro-level studies also allow in-depth analysis that measures the magnitudes of demographic attributes' impact and the ownership of household appliances on energy consumption.

Several micro-level studies on the electricity use in Indonesian households have been conducted. Kusumaningrum (2018) applied quantile regression on Indonesian household surveys' cross-section data to analyze the responsiveness of residential electricity demand to changes in electricity price. Wijaya and Tezuka (2013) employed multiple linear regressions on data of 100 households in each city of Bandung and Yogyakarta to estimate the income elasticity of electricity consumption based on differences in cultural background. Romadhoni and Akhmad (2020) studied household electricity demand in South Sulawesi. They applied multiple linear

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regressions on cross-section data of household samples. However, previous studies mentioned used cross-section data with a fewer samples and oneyear observation.

The present paper aims to expand the study of residential electricity demand in Indonesia using panel data to utilize both between-variation and within-variation in electricity consumption among households in Indonesia. Specifically, this paper asks what are the price elasticity and income elasticity of residential electricity demand in Indonesia? This paper utilizes SUSENAS household surveys documenting annual residential consumption in Indonesia for 2011-2013.

The electricity demand is measured as the function of own price, household income, family characteristics, house size, holdings of home appliances, and rural-urban characteristics of the household (Ang et al. 1992; Zhou & Teng, 2013). This model is static since it assumes instantaneous adjustment to new equilibrium values when prices or income change. The static model is understood to estimate intermediate-run elasticities of price and income that are typically somewhere in between short-run and long-run dynamic models estimates (Dahl, 2012). The present paper uses an average price as a function of the amount paid and electricity used. However, this approach is likely to present endogeneity issues, which will be discussed later in the method section.

The rest of the paper presents a brief background of Indonesia electricity demand in Section 2. Section 3 describes the overview of previous studies related to residential electricity demand. Subsequently, the method used in this research and data are presented in Section 4. This section also presents some stylish facts about the distribution of electricity usage in the Indonesian residential sector. Section 5 analyzes the estimation results. The conclusion is given in the final section.

Indonesia's Electricity Demand

Indonesia has experienced growing electricity demand, driven by robust economic growth in several sectors, including the consumer sector. During the 2009–2019 period, Indonesia's electricity sales in the household sector rose from 54,945 GWh to 102,917, with an average increase of 6.5% per year (National Energy Council, 2019). It is estimated that Indonesia's peak electricity demand could triple between 2010 and 2030 in a standard case, to 77.3 GW, mainly contributed by air conditioners and several appliances such as refrigerators and lighting (McNeil, Karali, & Letschert, 2019). This demand could be much higher since Indonesia would adopt more electric vehicles for the next several years. Electric cars have a potential of 10–20% of 1.2 million vehicles sold per year in Indonesia and a total sales of 1.5 million electric cars by 2030 (Gaikindo, 2020; McKinsey & Company, 2020).

Meanwhile, Indonesia's electricity price has been kept low by the state electricity enterprise (PLN), adhering to the government's mandate. PLN has little control over the retail price of electricity because the Ministry of Energy and Mineral Resources has kept the price low for a political purpose (Guild, 2020). Among ASEAN countries, the electricity tariff in Indonesia for non-subsidized household users is around 11 cents USD/kWh, still cheaper than electricity price in Thailand (12.41 cents USD/kWh), Singapore (19.97 cents USD/kWh), and the Philippines (18.67 cents USD/kWh) (Digital Energy Asia, 2018). Low electricity price is a burden to PLN as the main provider of electricity in Indonesia.

Although sold at a low price, PLN's operations are marked by high generation and transmission costs because PLN's choices of energy sources are quite costly, such as oil-based fuels and coal, while renewable energies—hydro and geothermal—require a high initial investment. Moreover, the mountainous geographical features of the Indonesia archipelago require intensive transmission and distribution systems. Since the Asian financial crisis in 1997–1998, it has been difficult for PLN to generate profit from its operation (Damuri, 2013). Any surge in oil, coal, and exchange rate could turn PLN's profit to loss. For instance, during the 2011–2019 period, PLN's annual profit ranged from Rp3.2 trillion to Rp14 trillion. In 2013, however, PLN incurred huge losses of Rp29.5 trillion due to rupiah depreciation (Dewanto, 2014). Despite being a monopolist in the retail electricity industry, PLN is vulnerable to energy and exchange rate fluctuations. The long-term issues that are affected by this price setting ares not only financial statements but also future investments.

The mainary issue for PLN expansion in the future is its ability to adopt renewable energies. Since PLN was given the mandate to keep selling prices low, it has slashed production costs by relying on coal-fired power plants. Indonesia has sufficient domestic supply and government controlled coal price. Due to the abundance, the contribution of coal-fired power plants reached 61% of total electricity production in 2019 (Banjarnahor, 2019). However, heavy reliance on coal creates a hazardous environmental impact, increasing health dangers and acid rains (The U.S. Energy Information Administration, 2020).

LITERATURE REVIEW

A meta-analysis of residential electricity demand found that the short-run price elasticity ranged from -0.948 to 0.61 with an average of -0.228. While for the long-term price elasticity is estimated to range from -4.2 to 0.6 with an average of -0.557. Meanwhile, the short-run income elasticities ranged from -0.45 to 1.265 with an average of 0.239, and the long-run income elasticities ranged from -0.89 to 4.45 with a mean of 0.239 (Zhu et al., 2018). The empirical studies on residential electricity demand that focus on income and price elasticities estimates are summarized in Table 1. Most studies conducted in the developed countries showed inelastic price elasticity of electricity demand. However, there is mixed empirical evidence in developing

Table 1. Empirical Results of The Estimation of the Electricity Demand Function

Sources	Price Elasticity		Income Elasticity		Study Period	Countries
	Short-Run	Long-Run	Short-Run	Long-Run		
Ang, Goh & Liu 1992	-0.35		1.0		1972-1990	Singapore
Burke & Abayasekara 2018	-0.1	-1			2003-2015	US
Stern & Akmal 2001		-0.95		0.52	1969-1998	Australia
Zhou & Teng 2013	-0.35		0.14		2007-2009	China
Shi, Zheng & Song 2012	-2.477		0.058		2008-2009	China
Phu 2020	-1.06 to 0.27		-0.02 to 0.39		2016	Vietnam
Tiwari & Menegaki 2019	-0.21		0.40		1975-2013	India
Filippini & Pachauri 2004	-0.5 to -0.3		0.6			India
Burke & Kurniawati 2018	-0.15 to -0.2	-0.4			1992-2015	Indonesia
Arnaz 2018	-0.15	-0.33	0.25	0.53	2000-2010	Indonesia
Al Irsyad, Nepal & Halog 2018	-0.20		-0.17		1969-2015	Indonesia
Wijaya & Tezuka 2013			0.103 to 0.21		2011	Indonesia (Bandung & Yogjakarta)
Romadhoni & Akhmad 2020			0.02 to 0.102		2020	Indonesia (South Su-lawesi)
Kusumaningrum 2018	-0.95 to -0.84		0.29 to 0.43		2011 and 2014	Indonesia

countries. On the one hand, some studies show an inelastic price elasticity. For instance, own-price elasticity is estimated between -0.5 and -0.21 in India (Filippini & Pachauri 2004; Tiwari & Menegaki 2019). On the other hand, an elastic price elasticity was found in several studies. For example, Shi et al. (2012) applied Ordinary Least Squares (OLS) to China's family panel studies and found the price elasticity of demand to be greater than -2.

Previous micro studies at the household level have confirmed that electricity consumers have inelastic price elasticity. For instance, Kusumaningrum (2018) found the elasticity of price of -0.95 and -0.84 using OLS and quantile regression. The Indonesian residential sector has also been found to have inelastic income elasticity. A study by Arnaz (2018) discovered that income elasticity for residential electricity demand was around 0.25 in the short-run and 0.53 in the long run. Growth in household income led to a gradualincrease in electricity usage.

Only a few micro-level studies have investogated Indonesia's residential electricity demand. Therefore, the present paper estimates nationwide household electricity demand, especially for elasticities of price and income. Moreover, this study incorporates household lifestyles that can contribute to electricity usages, such as household size, rural-urban classification, and home appliances (Phu, 2020; Shi et al., 2012).

METHOD AND DATA

Model For Residential Electricity Demand

The present paper estimated electricity demand using a static model. Therefore the estimation elasticities was not short-run nor long-run elasticity. Dahl (2012) interpreted a static model estimation of price and income elasticities as intermediate-run elasticities.

This paper postulated that electricity consumption was affected by household income, the price of electricity itself, and the heterogeneous characteristics of households. These characteristics icluded ownership of electrical appliances, size of the house , profile of household members, and the location of the house. However, this paper selected the most important factors of household electricity use based on previous studies. Two of these and the main variables of interest were income and price elasticity. Next were lifestyle-related variables such as the size of the house, household appliances, the number of household members, age of the thead of household, location of the house and educational background (Ang et al., 1992; Phu, 2020; Shi et al., 2012; Zhou & Teng, 2013). Household appliances included in this estimation consist of refrigerators, cable TV, air conditioners, water heaters, desktop computers, and electric stoves. The house location variable defines whether a households was located in rural or urban area. Following the previous explanation, the single equation static model (Shi et al., 2012; Zhou & Teng, 2013) can be expressed as equation 1

where $\ln E_{it} \ln E_{it}$ is the logarithm value of the annual household electricity consumption; $\ln(PE)_{it} \ln(PE)_{it}$ is the electricity price in logarithm value; $\ln(Income)_{it} \ln(Income)_{it}$ is the household income in logarithm value; $\mathrm{famsize}_{it} \mathrm{famsize}_{it}$represents family size; $\ln \mathrm{homesize}_{it} \ln \mathrm{homesize}_{it}$ is the log value of house area; $hhedu\ _{it} hhedu\ _{it}$ is the educational background of the head of household; $\mathrm{hhage}_{it} \mathrm{hhage}_{it}$ represents the age of household heads; home appliances are $\mathrm{refrigerator}_{it}$ $\mathrm{refrigerator}_{it}$, $\mathrm{cabletv}_{it} \mathrm{cabletv}_{it}$, aircon_{it} aircon_{it}, $\mathrm{waterheater}_{it} \mathrm{waterheater}_{it}$, and $\mathrm{desktoppc}_{it} \mathrm{desktoppc}_{it}$ and have dummy value 1 if the household own at least one appliance

$$ln\, E_{it} = \beta_0 + \beta_1\, ln(PE)_{it} + \beta_2\, ln(Income)_{it} + \beta_3 famsize_{it} + \beta_4 ln\, homesize_{it} + \beta_5 hhedu\ _{it} + \beta_6 hhage_{it} + \beta_7 refrigerator_{it} + \beta_8 cabletv_{it} + \beta_9 aircon_{it} + \beta_{10} waterheater_{it} + \beta_{11} desktoppc_{it} + \beta_{12} ruralurban_{it} + \varphi_t + \pi_{it} \tag{1}$$

and 0 other; $\text{ruralurban}_{it}\text{ruralurban}_{it}$ is the rural or urban dummy variable.

Using the logarithm value, the model's coefficients represented the elasticity of the dependent variable with respected to the independent variables. In other words, the model coefficients were the estimated percent change in the dependent variable for the percent change in the independent variable (Gujarati, 2003; Kacapyr, 2020). Meanwhile, some independent variables were represented in linear value (family size, educational background, and household heads age) or dummy variables (home appliances and whether the dwelling located in rural or urban areas). Each increase in linear value estimated the percent change in the independent variable, while in dummy variables, the absence or presence of some categorical effect estimated the percent change in the independent variable (Gujarati, 2003).

The income elasticity variables may correlate with lifestyle-related variables. Thus, excluding lifestyle-related variables—demographic characteristics, size of house area, and appliance ownership—could inflate the coefficient of income elasticity. This study controlled for these variables to better estimate income elasticity. However, this approach may result in more short-run elasticity because it does not capture the full long-run effect of income changes on electricity demand, as income affects the level of appliance ownership, dwelling size, etc., which in turn influences electricity demand (Espey & Espey, 2004).

However, since the tariff schedule remained stable over the study period, the fixed-effects (FE) model may not work very well for small variations in the price variables. Hence, this study used random-effect models to estimate price elasticity. The random-effects model uses between-subject variations plus includes the time-series variation for estimating price elasticity with little variability within subjects. Moreover, a random-effects regression model allows for the direct inclusion of individual-specific, time-invariant factors affecting the dependent variable— such as dwelling size, family size, and rural-urban classification. The random-effects model was estimated using the generalized least squares (GLS) technique. As a comparison, this study also provides pooled OLS estimation. Besides, this study employed a FE regression model to provide a better estimation of income elasticity. The FE regression model provides a means for controlling omitted variable bias.

Price Measurement And Estimation Issues

As mentioned before, this paper used the average price of electricity for residential users. The average price is obtained by dividing electricity payment bills by the household by the electricity used in kWh. Each household pays different basic tariffs based on power capacity and different taxes on public lighting based on district regulation. The combination of differences in power capacity and tax districts creates price variations among households. There are two issues following this approach, namely i) whether the average price is the proper price variable and ii) whether the average price is endogenous or exogenous to electricity demand.

There is a debate in the literature on whether consumers respond to the marginal price or the average price. Theoretically, in economics, the consumers respond to marginal prices. However, Alberini and Filippini (2011), citing Shin (1985), that households will respond to average price rather than to actual block marginal price. This may be because consumers paid attention to their bills rather than to the price structure (Ito, 2014).

This paper's regression was likely to have simultaneity issues due to the average price measure. Since there is a fixed tariff on electricity bills, the average price will be lower if the households use more electricity. The dependent variable on the left-hand side affects an independent variable on the right-hand side of the equation. However, the average price is always expected to exceed the marginal price because the fixed tariff component has a substantial amount on the electricity billing. In this paper, electricity quantities affected the price variable in the model, producing biased coefficients that led to overestimating the effect size of price elasticity in regression models.

Table 2. Descriptive Statistics of...

Variable	Obs	Unit	Mean	Std. Dev.	Min	Max
Electricity use	13077	kWh/month	121.036	102.247	2	698
Price	13077	Rupiah/kWh	683.585	497.871	45.946	4333.333
Expenditure	13077	Rupiah/month	2,768,826.9	2,744,184.1	255,552.38	1.618e+08
House Area	13077	meter sq.	77.477	49.331	3	900
Family Size	13077	People	4.141	1.728	1	17
Household Head Age	13077	Years	48.864	12.75	16	98
HH Education	13077	Years	8.766	3.773	0	18
Electric Stove	13077	Present=1 Not Present=0	.007	.085	0	1
Cable TV	13077	Present=1 Not Present=0	.144	.351	0	1
Air Conditioner	13077	Present=1 Not Present=0	.043	.203	0	1
Water Heater	13077	Present=1 Not Present=0	.052	.223	0	1
Refrigerator	13077	Present=1 Not Present=0	.489	.5	0	1
Desktop PC	13077	Present=1 Not Present=0	.081	.273	0	1
Urban Rural	13077	Urban=1 Rural=0	.58	.494	0	1

National Socio Economic Survey for Indonesia (SUSENAS) 2011–2013, Central Bureau of Statistics

Applying the actual marginal price to the estimation was difficult due to fixed tariffs and variables such as taxes that vary across power capacity and districts. This paper needs information about tax regulation in every district to formulate each household price. Therefore, this paper uses a more convenient average price method.

Data

This paper used annual nationwide household-level data called the Indonesian National Socio-Economic Survey (SUSENAS) published by the Indonesia Central Bureau of Statistics (BPS) from 2011 to 2013 (Central Bureau of Statistics, 2014) to investigate electricity demand The survey was conducted every March from 2011 until 2013 and covered 4,359 household samples from all regions in Indonesia. Therefore, there were three datasets for every household that each representing March monthly consumption of the households. The March monthly consumption represented households consumption of the corresponding year.

The 2011–2013 panel data contains information about family consumption, family characteristics, dwelling information, house materials, and other household-related information. The data provide information about electricity consumption in kilowatt-hour (kWh) a month, nominal electricity expenditure a month (Rp), total household expenditure per month, household size, age, education, dwelling area, appliance ownership, grid capacity, and characteristics of rural or urban. This study obtained the data of average electricity price by dividing the electricity bills of a household (Rp) by the kWh usage of the household. The electricity bills and the kWh usage of March represented the electricity consumption of the corresponding year. Moreover, this study used total expenditures as a proxy for a household's income.

This study used 2011-2013 panel data because at the time of this study, BPS lastly conducted household panel data surveys in 2013, and the data was widely published to the public. Newer surveys of BPS have been cross-section data with different samples every year.

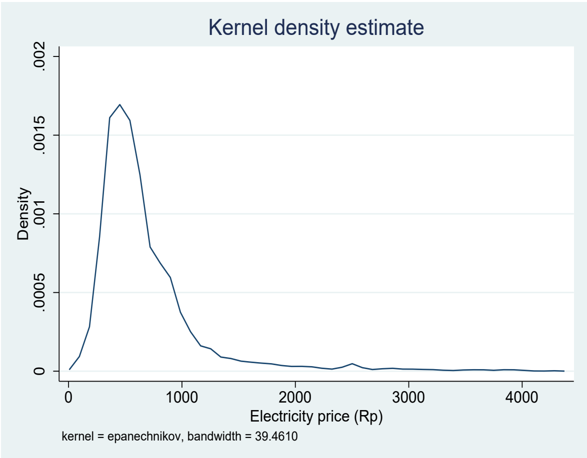
Table 2 shows the descriptive statistic of variables used in the estimation of residential electricity consumption. There are 13,077 observations and 4,359 households represent all regions in Indonesia. However the majority of observations is located in Java region. Each group represents three years of observation of

Table 3. Data Distribution Based on Region

Region	Frequency	Percent
Sumatera	3,846	29.41
Java	5,460	41.75
Bali & Nusa Tenggara	840	6.42
Kalimantam	1,122	8.58
Sulawesi	1,386	10.60
Maluku & Papua	423	3.23
Total	13,077	100.00

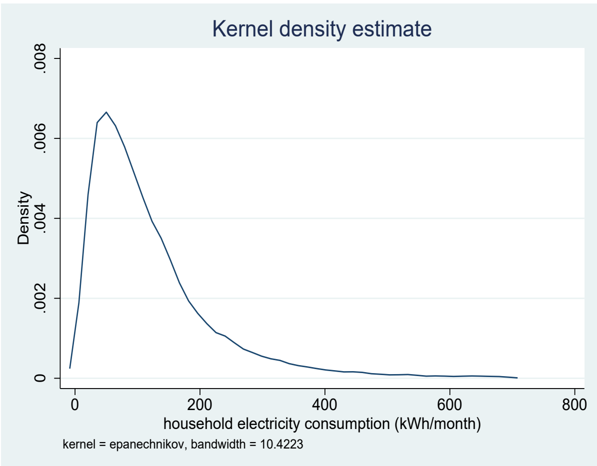
National Socio Economic Survey for Indonesia (SUSENAS) 2011–2013, Central Agency on Statistics

households from 2011 until 2013. The sample can be considered as large. The average monthly electricity usage in the Indonesian residential sector is around 113 kWh.



National Socio Economic Survey for Indonesia (SUSENAS) 2011–2013, Central Bureau of Statistics

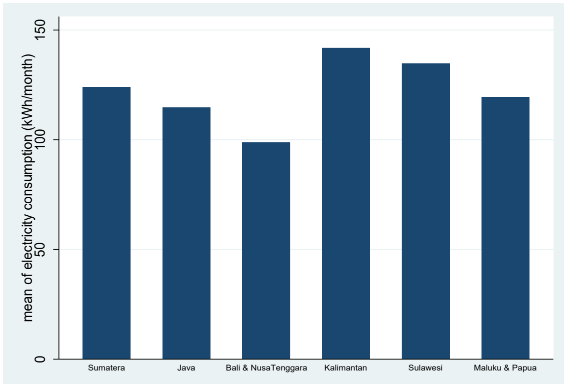
Figure 1. Kernel density of household electricity consumption (kWh)



National Socio Economic Survey for Indonesia (SUSENAS) 2011–2013, Central Bureau of Statistics

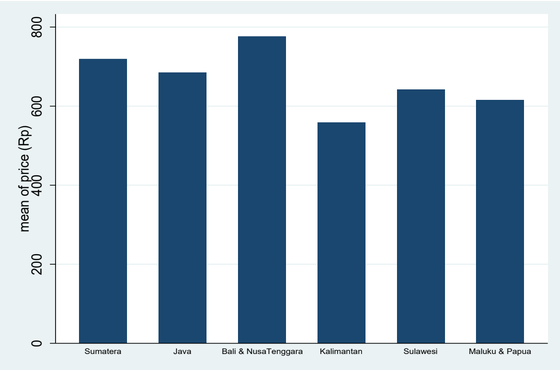
Figure 3. Kernel density of the price of electricity (Rp)

Figure 1 depicts the curve of the Kernel density estimate of household electricity consumption. As shown on the graph, electricity consumption in the household sector is distributed primarily between 20 kWh and 200 kWh per month. Hence, household electricity consumption varies among households. Moreover, there is a regional disparity in household electricity consumption, as illustrated in Figure 2. For instance, higher electricity consumption per capita is found in Sumatera and Java islands, while lower electricity consumption can be found among households in the Nusa Tenggara islands. In developing regions such as Kalimantan and Sulawesi, families consume higher electricity. East Kalimantan province, for instance, has electricity demand growth above the national average (Puspa, 2019).



National Socio Economic Survey for Indonesia (SUSENAS) 2011–2013, Central Bureau of Statistics

Figure 2. Household Electricity Consumption Across Regions



National Socio Economic Survey for Indonesia (SUSENAS) 2011–2013, Central Bureau of Statistics

Figure 4. Electricity Price Across Regions

Electricity price variation is significant as presented using the curve of Kernel density in Figure 3. The range of average electricity price is between Rp100 per kWh and Rp1,000 per kWh. Households experience different average electricity prices because the PLN pricing scheme implements different prices based on the capacity of the home network connection. Figure 4 illustrates the regional disparity of the price of electricity due to different tax regulations in districts. There isenough variation in average electricity prices among households and regions.

This paper also presents a correlation matrix among dependent variables before presenting the estimation results (see Appendix 1, Table 3). The matrix shows that electricity use has a negative correlation with electricity prices. On the contrary, electricity use has positive correlations with household income level, house area, family size, and several home appliances included electric stove, cable TV, air conditioner, water heater, refrigerator, and desktop PC. Moreover, living in an urban area has a positive impact on the amount of electricity consumption. The age of the head of the household has a low negative impact on the use of electricity while the level of education has a positive effect. The matrix implies a multicollinearity problem in estimating electricity demand. However, collinearity diagnostics through variance inflation factor suggests a low degree of multicollinearity (see Appendix 1, Table 4).

ESTIMATION RESULTS

Base Results

The study estimated baseline results using econometric specifications that include only price and income variables. The estimation used an OLS model and a random effect generalized least squares (GLS) model. Additionally, the FE model is used to estimate specifically for income elasticity. The results are reported in Table 5 that shows the parameters are statistically significant. They imply that price and income elasticity affect household electricity consumption.

The study used an OLS as a based model which is simply an OLS technique run on panel data. Hence, all individually specific effects were completely ignored because a lot of basic assumptions like orthogonality of the error term were violated (heteroscedasticity). Eliminating the heteroscedacity, this study employed a random effect generalized least squares (GLS) model by implementing an individual specific time-invariant factors affecting the dependent variable in the model which was assumed to be random. Moreover, this study also utilized the FE model that provided a means for controlling for omitted variable bias. It is useful for estimate the income effect when income is vary over time. Therefore, by implementing three ways of estimation, we could compare the effect of between-subject variation and also the effect of within-subject variation.

This study applied three specifications in each model to better understand the impact of each variables. The specification (1) only estimated the impact of electricity price and income of households to electricity consumption. The specification (2) contained all the variables of the specification (1) and household characteristics, such as the number of household members, household head age, household head education and the rural-urban categories of the dwelling. Meanwhile the specification (3) incorporated all variables including household appliances.

In the base model, price and income affected electricity consumption quite considerably. For

Table 3. Correlation Matrix Among Dependent Variables

	Elec. Use	Price	Income	House Area	Fam. Size	HH Age	HH Edu	Electric Stove	Cable TV	Air Con	Water Heater	Refrige-rator	Desktop PC	Urban Rural
Electricity use	1													
Price	-0.464***	1												
Income	0.471***	0.110***	1											
House Area	0.202***	0.0707***	0.271***	1										
Family Size	0.147***	0.0125	0.408***	0.105***	1									
Household Head Age	-0.0143	-0.00417	-0.113***	0.168***	-0.0753***	1								
HH Education Years	0.262***	0.101***	0.437***	0.152***	0.0277**	-0.334***	1							
Electric Stove	-0.0130	-0.0106	-0.0325***	-0.0336***	-0.0189*	0.00134	-0.0103	1						
Cable TV	0.0812***	0.0452***	0.138***	0.0372***	0.0295***	-0.0325***	0.103***	0.0158	1					
Air Conditioner	0.209***	0.114***	0.292***	0.180***	0.0131	-0.0280**	0.244***	0.0171	0.144***	1				
Water Heater	0.114***	0.0186*	0.155***	0.0914***	0.0206*	-0.0233**	0.141***	0.00391	0.188***	0.145***	1			
Refrigerator	0.439***	0.0823***	0.492***	0.262***	0.0728***	-0.0433***	0.384***	-0.0196*	0.125***	0.205***	0.159***	1		
Desktop PC	0.210***	0.0733***	0.315***	0.177***	0.0352***	-0.0302***	0.328***	-0.0158	0.0612***	0.233***	0.115***	0.251***	1	
Urban Rural	0.217***	0.131***	0.289***	0.00277	0.0203*	-0.0175*	0.249***	-0.0122	0.0408***	0.142***	0.0373***	0.259***	0.154***	1

Table 4. Multicollinearity Diagnostic

```
reg log_kwh log_price log_expend log_housearea fam_size hh_age hh_edu_years electric_stove cable_tv air_con
water_heater refrigerator desktop_pc urban_rural power_cap
>  district_id fwt3, vce(robust)

Linear regression                               Number of obs     =     12,296
                                                F(16, 12279)      =    1373.50
                                                Prob > F          =     0.0000
                                                R-squared         =     0.6495
                                                Root MSE          =     .49411

--------------------------------------------------------------------------------
               |               Robust
       log_kwh |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
     log_price |  -.8923099    .008721  -102.32   0.000    -.9094045   -.8752153
    log_expend |   .3256501   .0109734    29.68   0.000     .3041405    .3471598
 log_housearea |   .0763021   .0095609     7.98   0.000     .0575612    .0950431
      fam_size |   .0119216   .0030693     3.88   0.000     .0059054    .0179379
        hh_age |   .0030201   .0004101     7.36   0.000     .0022161     .003824
  hh_edu_years |   .0038045   .0015292     2.49   0.013      .000807     .006802
electric_stove |   .0040933   .0607586     0.07   0.946    -.1150033    .1231898
      cable_tv |   .0095397   .0132294     0.72   0.471    -.0163921    .0354715
       air_con |   .1585253   .0230361     6.88   0.000     .1133709    .2036798
  water_heater |   .0000997   .0206746     0.00   0.996    -.0404257     .040625
  refrigerator |   .3594098   .0111081    32.36   0.000     .3376362    .3811833
    desktop_pc |   .0154304   .0168214     0.92   0.359    -.0175421     .048403
   urban_rural |   .1596247   .0101127    15.78   0.000     .1398023    .1794471
     power_cap |   .3363096   .0082774    40.63   0.000     .3200847    .3525345
   district_id |  -3.38e-06   2.17e-06    -1.56   0.120    -7.63e-06    8.79e-07
          fwt3 |   6.27e-06   5.47e-07    11.47   0.000     5.20e-06    7.34e-06
         _cons |     3.9714   .1598436    24.85   0.000     3.658081    4.284719
--------------------------------------------------------------------------------
```

```
. vif

Variable        |       VIF       1/VIF
-------------+----------------------
log_expend      |      2.13    0.469194
hh_edu_years    |      1.60    0.624544
refrigerator    |      1.49    0.669069
power_cap       |      1.41    0.710204
fam_size        |      1.31    0.764957
desktop_pc      |      1.23    0.813020
air_con         |      1.22    0.819540
hh_age          |      1.22    0.822077
urban_rural     |      1.20    0.832212
log_housea~a    |      1.20    0.834062
water_heater    |      1.08    0.922071
cable_tv        |      1.07    0.935188
log_price       |      1.06    0.942628
district_id     |      1.05    0.949909
fwt3            |      1.04    0.962431
```

Table 5. Estimation Result

SPECIFICATION	(1) Pooled OLS	(2) Pooled OLS	(3) Pooled OLS	(1) RE GLS	(2) RE GLS	(3) RE GLS	(1) FE	(2) FE	(3) FE
Ln(Price)	-0.874***	-0.896***	-0.892***	-0.853***	-0.884***	-0.885***	-1.777***	-2.512***	-2.816***
	(0.009)	(0.009)	(0.009)	(0.012)	(0.012)	(0.011)	(0.519)	(0.564)	(0.562)
Ln(Income)	0.512***	0.437***	0.326***	0.458***	0.405***	0.337***	0.330***	0.321***	0.305***
	(0.009)	(0.011)	(0.011)	(0.010)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)
Ln(Housearea)		0.121***	0.076***		0.100***	0.072***		0.046***	0.043***
		(0.010)	(0.010)		(0.011)	(0.011)		(0.014)	(0.013)
Family Size		-0.000	0.012***		-0.001	0.007*		-0.007	-0.007
		(0.003)	(0.003)		(0.004)	(0.004)		(0.005)	(0.005)
Household Head Age		0.004***	0.003***		0.004***	0.004***		0.019***	0.018***
		(0.000)	(0.000)		(0.001)	(0.001)		(0.002)	(0.002)
HH Education		0.013***	0.004**		0.016***	0.008***		0.004	0.002
		(0.002)	(0.002)		(0.002)	(0.002)		(0.004)	(0.004)
Electric Stove			0.004			-0.011			-0.032
			(0.061)			(0.057)			(0.050)
Cable TV			0.010			-0.019			-0.060***
			(0.013)			(0.013)			(0.014)
Air Conditioner			0.159***			0.148***			0.093***
			(0.023)			(0.025)			(0.034)
Water Heater			0.000			-0.008			-0.028
			(0.021)			(0.021)			(0.023)
Refrigerator			0.359***			0.303***			0.165***
			(0.011)			(0.013)			(0.016)
Desktop PC			0.015			0.020			0.004
			(0.017)			(0.018)			(0.025)
Urban Rural		0.192***	0.160***		0.209***	0.174***			
		(0.011)	(0.010)		(0.014)	(0.013)			
Constant	1.825***	2.230***	3.971***	2.609***	2.682***	3.799***	10.615***	14.287***	16.447***
	(0.137)	(0.156)	(0.160)	(0.161)	(0.178)	(0.177)	(3.289)	(3.559)	(3.546)
Observations	12,296	12,296	12,296	13,077	12,296	12,296	13,077	12,296	12,296
R-squared	0.594	0.617	0.650				0.118	0.136	0.150
Number of id				4,359	4,100	4,100	4,359	4,100	4,100

Robust standard errors in parentheses | *** p<0.01, ** p<0.05, * p<0.1

example, the price elasticity coefficient in the base pooled OLS model was -0.87, suggesting that every 10% of price increase could decrease electricity consumption by 8.7 %. Whereas in the same model, every 10% increase in income could increase electricity use by 5%. In other words, electricity demand in Indonesia was responsive to changes in prices and income.

The Price Elasticity

The estimated price elasticity presented negative coefficients in all econometric specifications as expected. It suggested that electricity consumption will decrease as the price increase. Numerically, the estimated elasticity of price is around -0.88 (Table 5). The estimated price elasticity was expected to be neither short-run nor long-run elasticity due to the static model. However, this study considered that as intermediate-run price elasticity, as mentioned before. It is comparable with the households' price elasticity in Vietnam, as Phu (2020) investigated. Irsyad et al. (2018) study found that Indonesian residential electricity demand in the period of 1969–2015 has price elasticity around -0.20. Meanwhile, the study by Arnaz (2018) that covering period between 2000 until 2010, the price elasticity was somewhere around -0.15. Similarly, the study by Burke & Kurniawati (2018) resulted in -0.15 to -0.20 of price elasticity. Therefore, the price elasticity of this study was higher than those of previous studies in Indonesia. This study found the price elasticity was inelastic, but household consumers were quite responsive to price changes.

The Income Elasticity

The income elasticity implied that income growth increased electricity less proportionally. In the base model, as mentioned above, the coefficient was 0.512. However, after including lifestyle-related variables, the magnitude was proved to be lower. According to the specification (3) (Table 5) of the random-effects model, an increase of 10% in the family income could increase 3.3% of electricity consumption. This result suggested that income effect magnitude was quite considerable to electricity consumption despite its inelasticity.

The different results of different models can be explained as follows: given that many variables were controlled, income elasticities in the specification (3) in Table 5 represents a more short-run effect of household income on electricity consumption. A household cannot change both the rate of utilization and the stock of appliances. Conversely, the specification (1) depicts a more long-run equilibrium where a household can adjust its electricity usage by adjusting the number of home appliances and utilization rates. This study also presented the fixed-effect model as a comparison. The income elasticity in the short-run and fixed-effect model was around 0.3. Meanwhile, the more long-run income elasticities in the specification (1) of pooled OLS and the random effect model were 0.51 and 0.46, respectively. In the more long-run model, households' electricity demand tend to be more income elastic.

Lifestyle-Related Variables

This study also investigated the effect of household characteristics other than income level on electricity consumption. The variables included were adapted from previous micro-level studies on residential electricity demand (Shi et al., 2012; Zhou & Teng, 2013). The number of family members, age of the head of household, educational background, home appliances, and rural or urban traits of household were the determinants of electricity consumption. It is necessary to note that the estimation below is ceteris paribus that presents individual variable effects if all other factors are held constant. The effects of each household characteristic are shown in Figure 5.

The present paper found mixed results of family size effect on electricity consumption. The results ranged from 0.007 to 0.012 in different econometric specifications. The results were significant but have a very low impact. The household head variable indicated the age of each family. It was estimated that household heads' age positively affected electricity consumption despite having a very low degree. The coefficients ranged from 0.003 to 0.019 in different specifications.

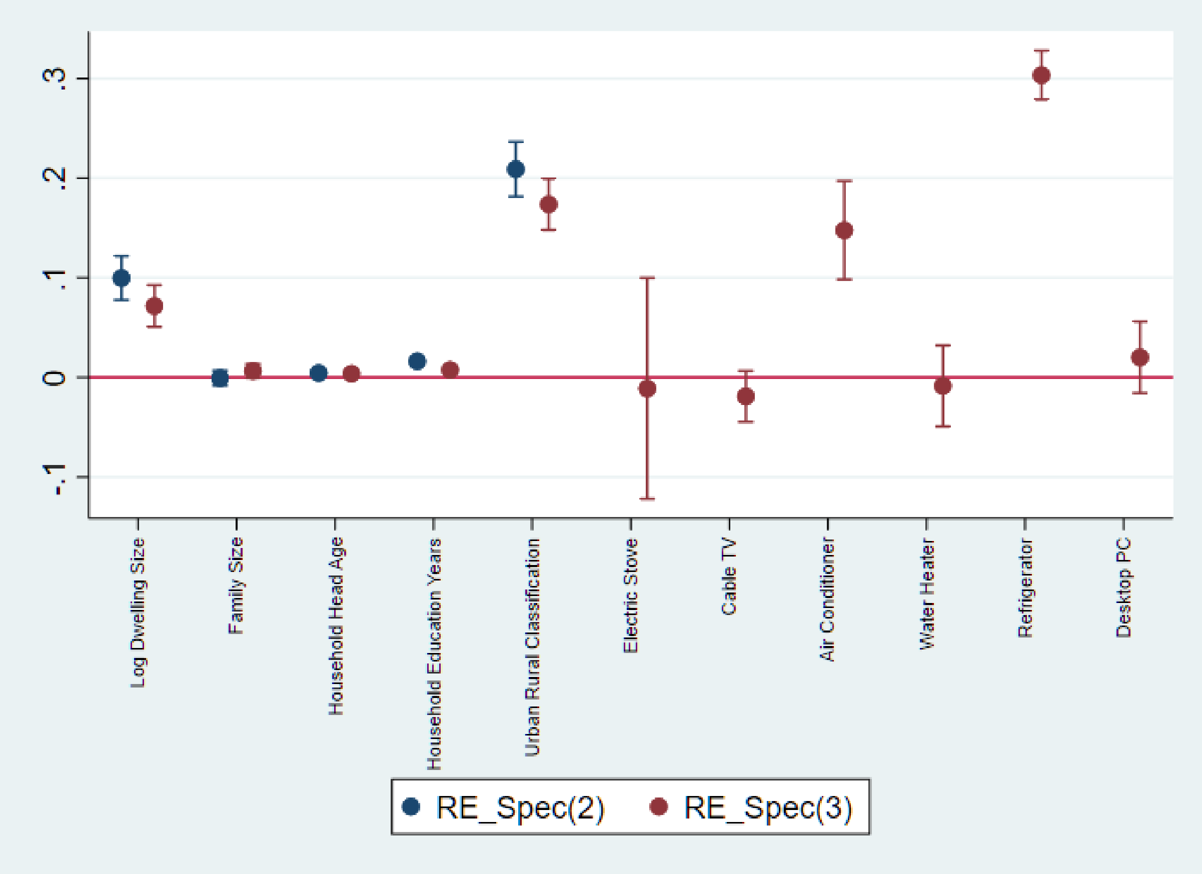


Figure 5. Household Characteristic Effect **on Electricity Consumption**

The educational background in the estimations reflected the head of the household s last education level. The higher value of the variable presented a higher level of education. The estimations suggested that families with a higher head's educational background used more electricity. In the specification (2) random effect model, each additional year of education showed an increase of electricity consumption by 1.6%. However, after controlling for home appliances, the estimated coefficients of the educational background were closer to zero (Table 5)—the effect changed to around 0.8%. Education has shown a positive impact on electricity consumption. The Indonesian government's attempt to improve minimum education could improve the demand for electricity in the future.

House area is proved to positively impact electricity consumption in this study (Table 5). Its positive impact may be the result of larger electricity usage for lighting in a larger area and cooling in the dry season. For instance, an increase of 10% of house size would increase 0.7% electricity consumption based on the specification (3) in the random effect model. The result was significant at a one percent level.

Another major determinant of household electricity consumption was expected to be house appliances. The usage of household appliances directly contributed to electricity consumption. Based on a previous study in Indonesia, an increase in the number of electronic equipment by 1% would increase electricity consumption by 0.296%(Romadhoni & Akhmad, 2020). Since the micro-level data consisted of household appliance ownership details, this paper investigated the magnitude of the impact of individual household appliances on electricity use.The appliances that could significantly affect electricity consumption were electric stove, cable TV, air conditioner, water heater, refrigerator, and desktop computer. According to the estimations, refrigerators and air conditioners has shown the highest usage of electricity in Indonesia. One explanation for this result is the tropical climate of Indonesia inducing frequent usage of air conditioners and refrigerators. Quantitatively, households with refrigerators consumed 30.3% higher electricity in the specification (3) random effect model, all else being equal. However, households that own air conditioners consumed 14.8% more electricity than households without an air conditioner, all else equal.

Reflecting the impact of refrigerators showing higher electricity consumption than that of air conditioners, a possible explanation is that most of the survey population use less hours of air conditioners and less frequently own an air conditioner. The kernel density of electricity consumption indicated that the majority of the survey population used around 100 kWh per month. Corresponding to that, the study by Batih and Sorapipatana (2016) found that the Indonesian class I households that use around 100 kWh per month have higher of refrigerator electricity usage than air conditioning electricity by 9.74 percent per month.

Specifically, desktop computer usage did not significantly affect household electricity consumption. Two other estimates of the effects of home appliances namely electric stove and water heater, were also not statistically significant. There was few number of households that owns electric stove and water heater in their home thereforethe result did not show a significant effect on electricity consumption. The estimated coefficient of cable TV ownership were also not significant.

This study also included an urban-rural dummy variable to investigate the difference between rural residents and urban residents. Estimates showed that people living in urban areas consumed about 17.4% to 20% more electricity than those living in rural areas. all else equal. Urban residents seemed to be more dependent on electricity than rural communities. Reducing electricity usage in rural areas is not complicated because of the abundance of cooking fuels and environmental conditions. For instance, in North Sumatra province, 64% of rural households still use firewood as an additional source of energy besides electricity and liquified petroleum gas (LPG) (Roubík et al., 2018). Easy access to the nearest forest encourages rural households to obtain free firewood.

Sensitivity Tests

The present paper administered sensitivity tests with various power capacities among households and with urban-rural classifications. Sensitivity tests aimed to confirm the estimation robustness of income elasticity and price elasticity. This study examined each price, power, elasticity and income by dividing the samples into several subsamples. The result in Table 6 (see Appendix 1) suggests that households with higher power capacity have lower price and income elasticities. For instance, the 450VA households have a price elasticity of -0.88 while the 2200VA household has a price elasticity of -0.79. The income elasticity in 450VA households was around 0.34, while the income elasticity in 2200VA was around 0.26.

Table 7. Sensitivity Check Urban Rural Interaction with Price and Income

VARIABLES	log_kwh
Rural*Price	-0.876***
	(0.015)
Urban*Price	-0.892***
	(0.014)
Rural*Income	0.325***
	(0.013)
Urban*Income	0.345***
	(0.012)
Ln(Housearea)	0.072***
	(0.011)
Family Size	0.007*
	(0.004)
Household Head Age	0.004***
	(0.001)
HH Education	0.008***
	(0.002)
Electric Stove	-0.012
	(0.057)
Cable TV	-0.019
	(0.013)
Air Conditioner	0.145***
	(0.025)
Water Heater	-0.008
	(0.021)
Refrigerator	0.303***
	(0.013)
Desktop PC	0.019
	(0.018)
Constant	3.904***
	(0.178)
Observations	12,296
Number of id	4,100

Meanwhile, the urban-rural classification examinedthe price elasticity by interacting prices with the rural-urban dummy variable. As shown in Table 7, it is found that price elasticity in urban areas is slightly higher than that of in rural areas. While the rural households' price elasticity was around -0.87, the urban households' price elasticity was around -0.89. The income elasticity of urban area was also found slightly higher than income elasticity in rural areas. Both results suggested that the demand for electricity in urban areas was more responsive to changes in electricity price and income than that of in rural areas.

CONCLUSION

This study results suggest that the intermediate-run price elasticity of residential electricity demand in Indonesia is inelastic, at around -0.88. The result is quite consistent with previous residential electricity demand studies in Indonesia. Despite inelastic demand, Indonesia's residential sector is quite responsive to electricity price changes. After controlling for household characteristics, house size, and domestic appliances, the income elasticity is around 0.34. Otherwise, this study found an income elasticity of 0.46. The electricity consumption of households in Indonesia is more income elastic in the long run since households could adjust their electricity consumption behaviour by changing home appliances and usage intensity.

Among the lifestyle-related factors affecting electricity consumption, dwelling size, cooling appliances, and urban-rural classification are significant explanatory variables. Refrigeration devices caused significantly higher electricity usage among households in Indonesia. This can be caused by the tropical climate in Indonesia that induces the more frequent use of cooling appliances. It was also found that rural households are less electricity dependent than urban residents due to the availability of alternative energy sources and easier access to fuelwood sources.

Because Indonesian residential sector was quite responsive to changes in electricity price, the government should prepare for higher electricity capacity as income growth will drive more electricity consumption. This study also found that the income elasticity becomes much smaller after controlling estimation for ownership of home appliances. It showed that households with higher income levels tend to have more home appliances than households with lower-income. Additionally, the price and income elasticity of residential electricity demand are likely to be useful for the energy demand analysis conducted by PLN and The Ministry of Energy and Mineral Resources. In addition to population growth and regulatory policies, Indonesia Energy Outlook also takes economic growth into account as a primary assumption (National Energy Council, 2019).

Some limitations of this study may provide valuable research avenues for futures studies. Due to the limited data availability , this research used short panel data that lack tariff schedule changes. Future studies can use long panel data that captures tariff schedule changes and employ dynamic panel data. This study also provided an insight that rural areas were less dependent on electricity. Thus, work should be done to investigate other causes of electricity consumption such as price, availability of electricity substitutes and complements, weather, and cultures.

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APPENDICES

Tables

Table 6. Sensitivity Check Using Power Capacity Subsamples

	450VA	900VA	1300VA	2200VA
Ln(Price)	-0.885***	-0.905***	-0.954***	-0.792***
	(0.014)	(0.017)	(0.039)	(0.106)
Ln(Income)	0.337***	0.321***	0.339***	0.259***
	(0.017)	(0.018)	(0.038)	(0.067)
Ln(Housearea)	0.048***	0.092***	0.143***	-0.061
	(0.016)	(0.015)	(0.033)	(0.078)
Family Size	0.006	0.001	0.027**	0.037
	(0.005)	(0.005)	(0.011)	(0.033)
Household Head Age	0.003***	0.005***	0.005***	0.006
	(0.001)	(0.001)	(0.002)	(0.004)
HH Education	0.008***	0.004	0.007	0.025
	(0.003)	(0.003)	(0.006)	(0.020)
Electric Stove	-0.001	-0.026	0.069	-0.409
	(0.072)	(0.133)	(0.149)	(0.319)
Cable TV	-0.034*	-0.027	0.032	0.114
	(0.021)	(0.019)	(0.040)	(0.081)
Air Conditioner	0.251***	0.175***	0.149***	0.193
	(0.081)	(0.034)	(0.050)	(0.136)
Water Heater	-0.011	-0.008	-0.067	-0.005
	(0.043)	(0.027)	(0.054)	(0.070)
Refrigerator	0.330***	0.237***	0.319***	0.859***
	(0.017)	(0.018)	(0.050)	(0.201)
Desktop PC	0.053	0.043*	0.001	-0.064
	(0.040)	(0.024)	(0.039)	(0.086)
Urban Rural	0.180***	0.156***	0.186***	0.130
	(0.017)	(0.019)	(0.062)	(0.178)
Constant	4.181***	4.833***	4.711***	5.075***
	(0.261)	(0.267)	(0.592)	(1.176)
Observations	6,462	4,554	1,078	165
Number of id	2,545	1,969	543	95