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Article

Estimation of demand system for household energy consumption : empirical evidence from Indonesia

Reference: Rasyid, Mohtar/Kristina, Anita (2021). Estimation of demand system for household energy consumption : empirical evidence from Indonesia. In: International Journal of Energy Economics and Policy 11 (6), S. 289 - 295.
https://www.econjournals.com/index.php/ijeep/article/download/11714/6130.
doi:10.32479/ijeep.11714.

IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(6), 289-295.

EJ EconJournals

Estimation of Demand System for Household Energy Consumption: Empirical Evidence from Indonesia

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Received: 25 June 2021 **Accepted:** 16 September 2021 **DOI:** https://doi.org/10.32479/ijeep.11714

ABSTRACT

This study aims to estimate the pattern of household demand for energy consumption such as electricity, water and fuel. The data used in this study is the publication of the Indonesia Family Life Survey (IFLS). To obtain comprehensive estimation results, this study uses the Quadratic Almost Ideal Demand System (QUAIDS) approach which is currently the standard in household demand estimation systems. The unit of observation used in this paper is more than three thousand households representing 13 provinces in Indonesia. The results show that the largest household energy consumption expenditure is electricity consumption followed by fuel and water. However, unlike the case of other commodities, the elasticity of spending on electricity is negative. Thus, an increase in household income will shift spending from electricity to consumption of other goods such as fuel, water and others. Meanwhile, the price elasticity for all energy commodities is inelastic. The increase in energy consumption commodity prices did not change demand much. This means that households are still very dependent on the supply of energy goods produced by the government. Therefore, appropriate policies are needed in determining the basic electricity tariff, fuel prices and clean water supply so that basic household needs can be fulfilled.

Keywords: Energy Consumption, System Demand, Household Expenditure, Quadratic Almost Ideal Demand System
JEL Classifications: D12, Q41, R20

1. INTRODUCTION

Household energy consumption has a relatively large portion in developing countries, including Indonesia. Several studies show that about 15%-25% of primary energy is consumed by households in developed countries (Dzioubinski and Chipman, 1999). The share of energy consumption by households in developing countries is certainly much larger. This fact shows that energy-related commodities are still very relevant to be researched. Energy consumption analysis is very important for a country's energy planning (Li and Just, 2018).

In the analysis of household energy consumption, several commodities identified as energy-based products include electricity, fuel and clean water. Consumption of electricity, fuel is very essential in household life in Indonesia. Consumption patterns for these commodities can be related to the level of poverty (Mohtar et al., 2020). In addition, price volatility of energy products, such as world oil, greatly affects the country's economy (Ayodele and Alege, 2021). Likewise, electricity consumption has become a basic need for households around the world (Tewathia, 2014).

As a country that is entering a transition period from a developing country to a developed country, Indonesia is currently facing a middle-income trap problem. This country is known as a country that has abundant natural resources, such as coal (Utomo et al., 2021). However, the quality of the environment is still experiencing problems that have not been maximally resolved (Setyari and Kusuma, 2021). Abundant natural resources still do not guarantee prosperity. The country with a fairly large household population in the world is still experiencing problems in fulfilling and managing energy-based commodities such as electricity, water and fuel.

Based on the above background, this study was conducted to analyze household consumption demand for energy-based commodities, including electricity, fuel and water in Indonesia. In addition, this research also includes one product that is very important in modern household life, namely telecommunications. Specifically, this study aims (1) to estimate the expenditure portion of each energy commodity, (2) to estimate the elasticity of household consumption expenditure for energy products, and (3) to estimate the price elasticity of energy products using either Marshallian Demand or Hicksian Demand approaches.

To answer this research question, this paper uses the Quadratic Almost Ideal Demand System (QUAIDS) approach. This approach can answer all three questions at once. The advantage of using this systems approach is that it is possible to estimate parameters associated with several products at once. In this research, parameter estimation for three energy commodities will be carried out, namely; electricity, water and fuel. As a control variable, this study will also use household expenditure variables for communication (telephone) activities.

The estimation system approach for energy consumption has actually been carried out by several studies. However, most of the research was conducted with the case of developed countries. In addition, the research data used is aggregate consumption over time (time series). Research on energy consumption patterns in developing countries using household micro data is still not widely found. To fill this gap, this research was conducted with a focus on the case of energy consumption in developing countries, namely Indonesia. In contrast to several previous studies, this study uses micro data on Indonesian households specifically for the consumption expenditure section. The household microdata used in this study is part of the Indonesian household panel data set collected since 1993. The last household survey was published in 2016 which was the fifth wave of the survey.

The organization of this paper is divided as follows. The next session contains a literature review which contains a review of previous studies. Furthermore, the methodology session contains a description of the data used as well as a discussion of the models and analytical techniques used in this study. The results and discussion section contains a description of the research results including estimates of income elasticity and price elasticity. This section will also discuss the empirical results obtained from this study. This paper closes with the conclusion section.

2. LITERATURE REVIEW

Research on energy demand has actually been done in several countries. This is because energy is a vital need in life. Energy products that are often studied in empirical studies are electricity, water and fuel. In some developing countries, the demand for energy will even determine the direction of national development policies in the long term.

In general, there are two approaches in estimating energy demand. The first approach is to estimate energy demand with a single estimate (Asaleye et al., 2021). This approach is carried out for specific commodity goods. Tewathia (2014) specifically examines the elasticity of Indian household electricity demand. The researcher found that the stock of appliances is the main variable that will determine the electricity demand in India. With almost the same spirit, Andruszkiewicz et al. (2019) proposes an alternative estimation model for electricity demand in Poland. Researchers found that electricity demand is still an essential part of European household needs. A study with a single estimation method for the case of water demand in Kuwait has been published by Alfalah (2021). Researchers specifically estimate the demand for water by local residents according to local country conditions. Research with a larger number of commodities has been carried out in Indonesia using a single estimate (Rasyid, 2021).

The single estimation approach has certain advantages. This estimate can be made only for specific commodities. In addition, single estimation is relatively easier to do with standard least squares and several other variants. However, the single estimation approach ignores the potential that consumption decisions between various similar products have very strong correlations. To some extent, if the linkage problem is very strong then a single estimate is potentially inefficient. Therefore, many researchers have decided to use alternative techniques to estimate various energy demands.

An alternative approach to estimating various energy needs is to use a system estimation system. In the demand system estimation literature, there are two models of estimation system approaches that are widely used, namely the Linear Expenditure System (LES) and the Almost Ideal Demand System (AIDS). Both systems of equations were originally developed using a linear system (Bye, 1992; Labandeira et al., 2006). Linear restrictions cause estimates to be very sensitive to very rigid assumptions. Currently, quadratic models have been developed for both the LES approach (Schulte and Heindl, 2016) and AIDS (Kratena and Wüger, 2010). Of course, the application of this system model is not only used by researchers to estimate the demand for consumer goods. Both the LES and AIDS approaches are now widely used to estimate various commodities with certain specifications. Nganau (2011) uses the LES approach to estimate a simple economic model in Africa. Meanwhile, Sheng et al. (2008) uses the AIDS model to estimate food demand in Malaysia.

The use of this very popular estimation system model has led to innovations from experts to provide solutions to problems that arise in analytical techniques. The system model certainly cannot be estimated using the Ordinary Least Square (OLS) approach. Several analytical techniques have been proposed in previous studies, starting from the Full Information Maximum Likelihood approach (Bye, 1992); Instrumental Variables (Labandeira et al., 2006); and the Two Step Maximum Likelihood approach (Li and Just, 2018). The more restrictions to be removed, the more complex the method introduced. Advances in computing technology have greatly helped the iteration process of calculations become easier. One form of system estimation model that is currently popularly used was introduced by Poi (2012) using AIDS which is more general by providing quadratic options.

The QUAIDS model is based on the following indirect utility functions:

$$\ln V\left(p,m\right)=\left[\left\{\frac{\ln m-\ln a(p)}{\ln b(p)}\right\}^{-1}+\lambda(p)\right]^{-1} \quad (1)$$

In this case ln a(p) is a function of the transcendental logarithm. The variables p and m are the price level and total expenditure, respectively.

$$\ln a\left(p\right)=\alpha_0+\sum_{i=1}^{k}\alpha_i \ln p_i+\frac{1}{2}\sum_{i=1}^{k}\sum_{j=1}^{k}\gamma_{ij}\ln p_i \ln p_k \quad (2)$$

The function above shows that p_i is the price of goods i for i= 1……k. Meanwhile b(p) is a price aggregator of the Cobb-Douglas type. The last fractions of the indirect utility functions in equation (1) are as follows:

$$b(p)=\prod_{i=k}^{k}p_i^{\beta_i}$$

and

$$\lambda(p)=\sum_{i=k}^{k}\lambda_i \ln p_i$$

The assumptions used in the QUAIDS model are adding up, homogeneity and Slutsky symmetry which can be expressed as follows:

$$\sum_{i=1}^{k}\alpha_i=1,\sum_{i=1}^{k}\beta_i=0,\sum_{j=1}^{k}\gamma_{ij}=0,\sum_{i=1}^{k}\lambda_i=0,\gamma_{ij}=\gamma_{ij}$$

The QUAIDS model will automatically imposes the above important assumptions to be fulfilled.

3. METHODS

This study uses household micro data published by the Indonesia Family Life Survey (IFLS). This survey has been carried out since 1993 and periodically collected data again in 1997, 2000, 2007 and 2014. This research on household consumption will use the results of the latest published household surveys. IFLS data has been widely used by researchers to analyze household behavior in Indonesia such as financial transfers between households and other related aspects (Mohtar, 2021).

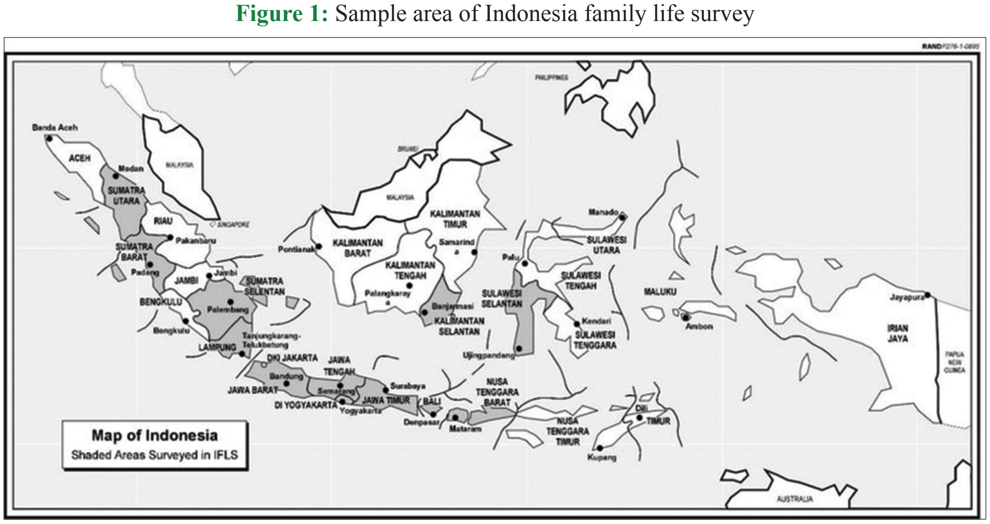
IFLS is a form of fairly representative household panel data. The sample selected was based on 1993 National Survey data representing more than 80% of the population in Indonesia. Approximately 13 provinces in Indonesia were selected as samples. In 2012, IFLS specifically published the results of data collection in eastern Indonesia. The coverage of IFLS provinces can be seen in Figure 1 as follows:

In accordance with the research objectives, the main commodity to be studied is energy-based products. Since the context of this research is to find out the overall pattern of household consumption, several energy commodities that are included in the analysis include: electricity commodities, clean water commodities for drinking and bathing, fuel commodities and commodities related to telecommunications needs.

In this study, micro household data from the publication of the national survey or publications from the Indonesia Family Life Survey (IFLS) and other relevant secondary data will be used. The data used consists of household consumption for several commodities, the price index for each commodity and total household expenditure. In addition, household micro data used in this study included the number of household members, household domicile status (village or city) and other household characteristics (Strauss et al., 2016).

IFLS households from the first to the last wave always experience an increase. Until the last wave, the number of households that were successfully surveyed reached more than 10 thousand

Figure 1: Sample area of Indonesia family life survey



households. In this study, not all households were selected as samples. With regard to expenditure data for electricity, water, fuel and telecommunications, around 3 thousand households were selected to provide answers to questions related to consumption. Some households that could not give a definite answer or even did not answer, were not included in the sample for this research.

Estimation of household consumption patterns will be carried out using a demand equation system model which is formalized as follows:

$$w_i = \alpha_i + \sum_{j=k}^{k} \gamma_{ij} \ln p_j + \beta_i \ln\left\{\frac{m}{a(p)}\right\}, \qquad i = 1,\ldots k \tag{3}$$

In this case w_i is the portion of consumption expenditure and p_j is the price level for the commodity in question. Meanwhile, m is the total household expenditure. The equation model (1) is known as the Almost Ideal Demand System (AIDS). In the empirical realm, the AIDS model can be expanded in two ways. First, this model is expressed in quadratic form so it is known as the Quadratic Almost Ideal Demand System (QUAIDS). Second, this model can be extended by adding demographic factors as a determinant of demand.

The quadratic version of the system of equations (3) above is as follows:

$$w_i = \alpha_i + \sum_{j=k}^{k} \gamma_{ij} \ln p_j + \beta_i \ln\left\{\frac{m}{a(p)}\right\} + \frac{\lambda_i}{b(p)}\left[\ln\left\{\frac{m}{a(p)}\right\}\right]^2 \qquad i = 1,\ldots k \tag{4}$$

The estimation of the coefficients in the AIDS equation can be done using the Feasible Generalized Non-Linear Least Square Estimation approach. In addition to parameter estimation, several important coefficients can be estimated using the Slutsky equation as follows:

$$\epsilon_{ij}^{c} = \epsilon_{ij} + \mu_i w_j \tag{5}$$

In this case $\in_{ij}$ is the price elasticity (compensated), ϵ_{ij} is the uncompensated price elasticity and μ_i is the income elasticity.

4. RESULTS AND DISCUSSION

As mentioned in the previous session, this research basically aims to estimate the coefficients in the QUAIDS model for electricity, water, fuel and telecommunications commodities. Technically, referring to the analytical model in equation (4), the estimated coefficients will consist of four groups, namely: alpha (α); beta (β); gamma (γ) and lambda (λ).

The household consumption data available in the IFLS is quite abundant. For research purposes, only four types of household consumption expenditure were analyzed. Consumption expenditure on other goods is not used in the calculation. Therefore, the total household expenditure as a proxy for the household income variable, is only limited to the total expenditure for electricity, water, fuel and telecommunications. The share of household expenditure in this study will also refer to the concept of the total expenditure in question. In addition, the commodity price variable in this study was not obtained directly because the available survey did not specifically ask about it. The price variable in this study is proxied by the purchase value for each of the commodities in question.

To simplify the analysis, in this study, each commodity is coded as follows: (1) for electricity; (2) for water; (3) for fuel and (4) for telecommunications. The code in the analysis will be placed after the underscore.

Table 1 presents data about descriptive statistics from the data used in this study. After thorough cleaning of the data, the number of observations included in the analysis was 3.72 households. The QUAIDS model requires information on the portion of consumption expenditure, the price of goods and the total expenditure. A brief description of each variable for each commodity analyzed can be seen in Table 1. Variable share is expressed in percentage units. Meanwhile, the variables of price and total household expenditure are each expressed in the form of a natural logarithm.

The main estimation results from this study are presented in Table 2. This table presents the results of calculating the estimated coefficient value of the QUAIDS model in equation (4). There are 22 estimated coefficients and almost all of them show a fairly high level of significance. There are only two coefficients that are not significant enough at the conventional level. When viewed from the overall model performance, it can be said that the estimation results are very good.

The first evaluation of this model is whether the quadratic model is better than the linear model? Technically this question can be stated as follows: is the lambda coefficient simultaneously significant enough? The estimation results show that of the four lambda coefficients that are calculated, only one coefficient is not significant. While others are significant up to the level of one percent. Simultaneous testing shows that the lambda coefficient is very significant. This indicates that the quadratic model, or QUAIDS, is more relevant than the linear AIDS model.

Table 1: Summary statistic of data

Variables	Obs.	Mean	Std. Dev	Min	Max
Share_1	3.272	0.3272	0.1476	0.0114	0.8993
Share_2	3.272	0.1837	0.1184	0.0018	0.8475
Share_3	3.272	0.2039	0.1304	0.0010	0.8495
Share_4	3.272	0.2852	0.1633	0.0078	0.9171
lnPrice_1	3.272	11.3541	0.8678	8.0064	14.9141
lnPrice_2	3.272	10.6379	1.0302	6.2146	15.8950
lnPrice_3	3.272	10.7791	0.7269	4.9416	14.8004
lnPrice_4	3.272	11.1370	1.0458	7.7832	15.4250
ln Exp	3.272	12.5827	0.7031	10.7579	16.0938

Source: Author calculation

Table 2: Main result of QUAIDS model

Parameter	Coef.	Std. Err.	z	P>z	Confidence Interval	
alpha_1	−0.35496	0.007016	−50.6	0.000	−0.36871	−0.34121
alpha_2	0.541566	0.009767	55.45	0.000	0.522424	0.560708
alpha_3	0.527022	0.010203	51.65	0.000	0.507024	0.54702
alpha_4	0.286373	0.008769	32.66	0.000	0.269187	0.303559
beta_1	−0.37285	0.003403	−109.56	0.000	−0.37952	−0.36618
beta_2	0.113326	0.004799	23.61	0.000	0.103919	0.122732
beta_3	0.062942	0.004984	12.63	0.000	0.053173	0.07271
beta_4	0.196582	0.004006	49.07	0.000	0.18873	0.204434
gamma_1_1	0.363609	0.002998	121.3	0.000	0.357734	0.369485
gamma_2_1	−0.10461	0.002455	−42.6	0.000	−0.10942	−0.0998
gamma_3_1	−0.0994	0.00262	−37.94	0.000	−0.10454	−0.09427
gamma_4_1	−0.1596	0.002389	−66.81	0.000	−0.16428	−0.15491
gamma_2_2	0.141528	0.002018	70.13	0.000	0.137573	0.145484
gamma_3_2	0.000525	0.001256	0.42	0.676	−0.00194	0.002988
gamma_4_2	−0.03744	0.001385	−27.03	0.000	−0.04016	−0.03473
gamma_3_3	0.166576	0.001838	90.62	0.000	0.162974	0.170179
gamma_4_3	−0.0677	0.001295	−52.28	0.000	−0.07024	−0.06516
gamma_4_4	0.264736	0.001403	188.75	0.000	0.261987	0.267485
lambda_1	−0.05563	0.000633	−87.94	0.000	−0.05687	−0.05439
lambda_2	−0.00018	0.000833	−0.22	0.827	−0.00181	0.00145
lambda_3	−0.0152	0.00081	−18.76	0.000	−0.01679	−0.01361
lambda_4	0.071016	0.000476	149.17	0.000	0.070083	0.071949

Source: STATA output

In the QUAIDS analysis, the coefficient values from the estimation results of the main model cannot be directly interpreted. Technically econometric, the coefficient describes the contribution of each factor to the share of expenditure of a commodity. Besides econometric interpretation, the most important analysis of this approach is to find the appropriate coefficient of income elasticity and price elasticity. The income and price elasticity coefficients cannot be directly obtained through the estimation results of the main model. The coefficients in Table 2 must be processed again to obtain estimated values for income and price elasticity.

Income elasticity (μ) can be obtained from the following formulation:

$$\mu_i = 1 + \frac{1}{w_i}\left[\beta_i + \frac{2\lambda_i}{b(p)}\ln\left\{\frac{m}{a(p)}\right\}\right] \quad (6)$$

Calculating the value of the elasticity coefficient using the above formulation for each case will be seen as a tiring routine job if done manually. The QUAIDS estimation technique introduced by Poi (2012) provides an easier solution for researchers who do not pay much attention to the complexity of calculations. The quaids command in STATA can display the results of the estimated income elasticity in the postestimation menu. Not only the calculation of income elasticity, the coefficient of price elasticity with reference to Marshallian Demand and Hicksian Demand can also be obtained directly.

Therefore, researchers can directly interpret the results of the calculation of income and price elasticity after the main model estimation results are significant. The income elasticity is proxied by the total expenditure elasticity. Meanwhile, price elasticity can be calculated automatically using either the reference price of the goods themselves (own elasticity) or the price of other commodity goods (cross elasticity). The relationship between income elasticity and price elasticity can be observed in the Slutsky equation as shown in equation (5).

Before calculating the income and price elasticity, first, the predicted portion of consumption expenditure for each energy item is estimated. The prediction results can be seen in Figure 2.

The result of calculating the predicted portion of household expenditure for energy needs is mostly for electricity expenditure (as much as 33%). Furthermore, the portion of energy expenditure is to buy fuel (21%) and the last is to purchase water (18%). The share of expenditure for telecommunications purposes is also relatively high (28%).

The next calculation is to estimate the income elasticity according to the formula in equation (6). The results of the calculation of the estimated income elasticity for various types of energy products in Indonesia can be seen in Figure 3 as follows:

Based on the calculation results, it is known that the average income elasticity for electricity consumption is −0.8858. This result is quite surprising because normally the value of the income elasticity coefficient is positive. This finding indicates that a 1% increase in household income will be responded negatively by electricity consumption. In other words, households will relocate their household budget for electricity if there is an increase in income. Several explanations can be given to explain this phenomenon. First, the number of households that have electricity in Indonesia is quite large (above 90%), so that electricity consumption may have reached a saturation point. Second, the conversion of electricity meters from a postpaid to a prepaid system allows households to make savings by setting usage according to their predicted needs. Third, electrical appliance technology that is increasingly energy efficient causes household electricity expenditure to be cheaper.

Figure 2: Predicted share of household energy consumption

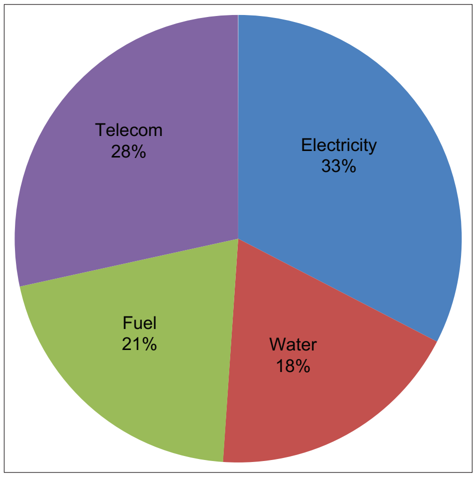
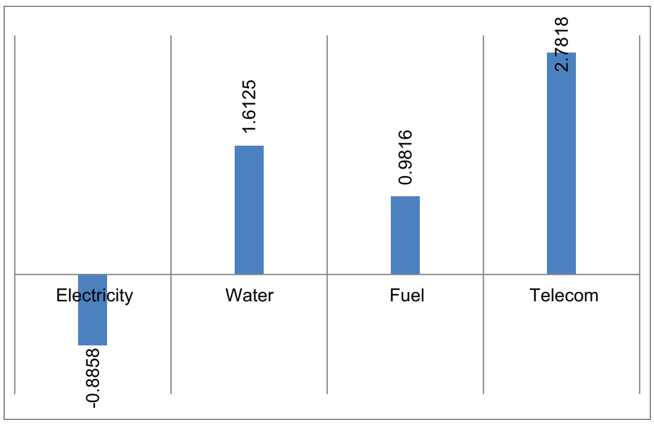


Figure 3: Elasticity of income for household energy consumption



This result is in line with the findings in India which found that the main determinant of electricity consumption is the use of electrical equipment (Tewathia, 2014).

Another result that needs attention is the income elasticity for average fuel consumption is 0.9816 (relatively inelastic). Dependence on world oil prices causes the conversion of the use of fuel oil to gas fuel relatively quickly. The relatively stable price of gas fuel causes the allocation of expenditure for this product to be relatively stable. The increase in household income will be responded by spending more on fuel. However, the response to an increase in fuel consumption due to an increase in household income is relatively small. The volatility of world oil prices, which has begun to be subdued, has become a determining factor in the sensitivity of demand on household incomes (Ayodele and Alege, 2021).

Furthermore, the estimation of the elasticity of household income for water consumption obtained relatively elastic results (1.6125). Although the share of household expenditure on water is relatively small, the income elasticity for water is relatively large in quantity. An increase of 1% of household income will be responded by an increase in water consumption of more than one percent. This result is different from the findings of the water demand study in Kuwait. Using the time series data approach, it is found that the income elasticity of water in Kuwait is relatively inelastic in the long run. In the short-term case, the income elasticity for water consumption is not significant at the conventional level (Alfalah, 2021).

Table 3: Price elasticity of household energy consumption

	Electricity	Water	Fuel	Telecom
Electricity	−0.523713	0.619035	0.592937	0.219894
Water	−0.455732	−0.503530	−0.269711	−0.383385
Fuel	−0.613844	0.051999	−0.149959	−0.259947
Telecom	0.185995	−1.067024	−1.114010	−0.819474

Table 3 presents the estimation results of the price elasticity of various types of energy commodities. The diagonal cells in the table provide an estimate of the average own-price elasticity. According to the theory conjecture, the price elasticity for all analyzed commodities is negative. That is, an increase in the price for each price will reduce consumption for the goods in question. The price elasticity of electricity and water is relatively the same, namely −0.5 while the price elasticity for fuel is −0.15. In general, it can be said that the price elasticity for energy products is relatively inelastic. As a basic need, the demand for energy commodities will be relatively stable even though the price of energy products increases. Household dependence on energy products is a normal thing in the world.

In addition to the estimation of own-price elasticity, Table 3 also presents the estimation results of cross-elasticity. For example, when the price of water or fuel increases, the demand for electricity also increases. On the other hand, if the price of electricity or fuel increases, the demand for water will decrease. The cross-elasticity estimation for the fuel in this study is quite unique. When the price of electricity increases, the demand for fuel will decrease. However, if the price of water increases, the demand for fuel will also increase. These results indicate that the relationship between electricity and other energy products is substitutive. Meanwhile, the relationship between water and other energy products is complementary. This interpretation certainly needs to be studied further by conducting further, more comprehensive research.

5. CONCLUSION

The results of research on the household demand system for energy consumption in Indonesia can be summarized as follows. First, household expenditure on energy is electricity. Expenditures on fuel and water are relatively less. Second, the elasticity of household income for energy consumption is positive, except for electricity expenditure. The income elasticity for electricity is negative. The three price elasticities for all energy goods are negative and relatively inelastic. In this case, the price elasticity of fuel is the least elastic. This means that the increase in fuel prices was responded to by relatively small changes in demand.

Based on the results of this study, it can be concluded that electricity and fuel are basic household needs that must be managed wisely by the government. Raising the basic price of electricity and fuel prices must be decided carefully so that the implications for household welfare are not too painful.

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