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Exploring socio-economic determinants of energy choices for cooking: the case of eastern Indonesian households

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Abstract
Globally, nearly 1.3 billion people have no access to electricity, and 3.0 billion people rely on 'dirty' fuel such as firewood and biomass for cooking and heating. In Indonesia, firewood is still the fuel of choice when cooking due to its low cost and abundant availability in rural areas. However, the adverse consequences of the indoor air pollution produced through cooking are neglected. Furthermore, the use of firewood for household energy is also associated with slash and burn practices, which drive deforestation and environmental degradation. The use of clean energy, therefore, is imperative for improving people's health and minimizing their environmental footprint. Having this insight, this study aims to examine the factors associated with households' choice of energy for cooking. Using Indonesia Family Life Survey-East, which specifically collected information from households in the eastern part of Indonesia, the study demonstrates that reliance on clean energy is highest among affluent households and households with better socio-economic indicators (including higher education, non-farm livelihoods, smaller sizes, and electricity connectivity). Households located in urban areas and households located closer to markets tend to rely more on gas for cooking energy. In contrast, poorer rural households residing in villages with abundant natural resources (i.e., with a high share of forests and farmland) generally use firewood as their main source of energy when cooking. The findings of this research also show that energy prices are important in explaining the use of clean or dirty fuel for cooking. It is suggested that efforts to enhance household clean energy use are driven by improved household economic status (especially income and education), access to markets, and stable energy prices. Policy interventions that account for energy and environment issues need to be designed to reduce the overuse of firewood for cooking energy in households living next to common property resources.

Keywords Dirty fuel · Clean energy · Households · Natural resources · Multivariate probit · Eastern Indonesia

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1 Introduction

Indoor air pollution resulting from the use of dirty fuels such as firewood, agricultural waste, and livestock manure, coal, and charcoal is currently considered a threat to global health and influences most of the population in developing countries. Bruce et al. (2002) suggest that air pollution emitted from inefficient stove combustion using dirty fuels is the biggest challenge for human health in developing countries. Dependence on dirty fuels is closely related to poverty, especially for people living in rural areas (World Health Organization, 2017). The most affected are generally women, who are usually responsible for cooking activities. The World Health Organization (2014) stated that approximately 2.8 billion people depend on dirty fuels for their household energy needs, and that more than 4 million premature deaths (pneumonia, stroke, heart disease, chronic lung disease, and lung cancer) can be attributed to indoor air pollution from cooking.

Indonesia has experienced a remarkable transition from dirty energy sources for cooking (firewood and fuel/kerosene) to cleaner ones (gas). In 2017, the percentage of households using firewood as their main fuel when cooking decreased to below 20% (Indonesian Bureau of Statistics 2017). The Asian Development Bank (2020) reported that more than half of Indonesian households (61.85%) mostly use a 3 kg liquefied petroleum gas (LPG) canister. Disaggregated by area, 72.53% of urban households depend on gas for their cooking energy, compared to 51.10% of their rural counterparts. This situation is even more striking when comparing western and eastern Indonesia. In western Indonesia, the transition to using LPG for cooking has been successful in many provinces, but in eastern Indonesia, many households are still very dependent on firewood or kerosene. For example, 89.1% of households in Maluku reportedly still use kerosene, while in Java, only 0.7% of households are kerosene-dependent. Prices of kerosene and LPG are still an issue, driving eastern Indonesian families to combine kerosene and firewood (rather than switch to LPG) to save money.

To reduce the cost burden for households as well as their reliance on kerosene, the Indonesian government has introduced a mega-project aimed to provide price subsidies for low-income households (Budya & Arofat, 2011; Thoday et al., 2018). This energy conversion project involved distributing a free-of-charge starter pack, consisting of a stove and a 3-kg LPG cylinder, to low-income households as an incentive to switch fuels (Asian Development Bank, 2020; Ministry of Energy & Mineral Resources, 2020). However, as with similar programs in Indonesia, the subsidized LPG program is problematic. Most consumers have to pay far higher than the subsidized price due to their dependence on small retailers that mark-up the subsidized prices of "authorized sellers." The program is further complicated by mistargeting; 70% of the highest-income households (i.e., household income in the highest 10%) reported using a subsidized 3 kg LPG canister, rather than the non-subsidized 12-kg LPG canister (Asian Development Bank, 2020).

Nevertheless, Indonesia is still experiencing one of the fastest deforestation rates in the world (Hansen et al., 2013). Conversion to oil palm plantations (Vijay et al., 2016), firewood collection and charcoal production are major drivers of deforestation in many countries (Lee et al., 2015; Win et al., 2018), and this is also true in Indonesia, where firewood remains a common fuel source due to its low cost for household budgets (Syaaf, 2018). However, the Indonesian peoples' dependence on such fuel is not balanced awareness of the associated costs (time spent collecting firewood, longer cooking times, comfort), or by information on the adverse influences of pollution produced. Based on information from the World Bank (2013), around 165,000 Indonesians died prematurely from respiratory

infections associated with burning wood inside the home even though the cause of death due to respiratory infection has been declined (Institute for Health Metrics & Evaluation Indonesia, 2019). However, other adverse consequences of indoor air pollution due to polluting fuels have been identified including lung cancer, ischemic heart disease, stroke, and chronic obstructive pulmonary disease (Gold Standard, 2017, HAPIT Indonesia, 2013). Understanding the demand for firewood plays a vital role in planning and designing policies for sustainable energy and natural resources. Earlier studies (Baul et al., 2018; Win et al., 2018) have shown the impact of the "energy ladder" on cleaner energy use in rural areas, noting that firewood demand is highest in rural villages and correlates positively with proximity to forests.

Having those insights, this study aims to examine the determinants of household energy choices for cooking in Eastern Indonesia, a region that is recognized as lagging in both economic and non-economic dimensions. It is presumed that by using the case of Eastern Indonesian households, the findings of this study will be relevant for policy intervention designed to encourage energy transition for households living near common property resources.

2 A brief review of household energy transition

Household cooking fuel falls into three categories, namely traditional fuels (firewood, animal waste, and plants), medium fuels (wood powder, charcoal, briquettes, coal, and kerosene), and modern fuels (LPG, biogas, electricity, vegetable oil, and solar power) (Malla & Timilsina, 2014). Different types of fuel produce different types of pollution; for example, burning wood using traditional stoves produces more air pollution than gas and electric stoves. Dirty fuels' detrimental influence on health is exacerbated by the lack of ventilation, as well as the design of stoves without chimneys (Hanna et al., 2016) resulting to severe household air pollution.

To explain household energy choices, the "energy ladder" and "energy stacking" models are commonly used (Campbell et al., 2003, Heltberg, 2004). The energy ladder model argues that households switch from one type of fuel to another based on the available energy use options and their own income. Under this model, households will climb the energy ladder as their income level rises. This model uses the above-mentioned classification of fuel sources, with traditional ones (firewood, crop residues, and dung cakes) at the middle, transitional ones (charcoal, kerosene, and coal) in the middle, and modern/advanced ones such as electricity, liquefied petroleum gas (LPG), and biogas at the top (Hosier & Dowd, 1987; Schlag & Zuzarte, 2008). Earlier studies estimated that modern/advanced sources can reduce indoor air pollution (Snider et al., 2018; Steenland et al., 2018). It has been empirically revealed that households with lower income tend to use cheap and locally available fuels, even when they are recognized as neither clean nor energy-efficient (Duflo et al., 2008). Energy consumption improves as household income increases (Bruce et al., 2002; Duflo et al., 2008).

On the other hand, the energy-stacking model argues that household energy switching behavior is not simply associated with income, as depicted in the energy ladder model, but holds that households might jump from traditional fuel to modern/advanced fuel regardless of income level. Proponents of this model argued that the energy switching behavior is driven not only by income, but also by complex interactions between the choice of technology and socio-cultural variables (i.e., education level, awareness, cooking behavior, etc.)

Fig. 1 Provinces covered in IFLS East (https://surveymeter.org/id/research/3/iflseast)

(Muller & Yan, 2018). Some studies have shown that several socio-economic factors, such as income, education, age, household size, household wealth, and domicile characteristics influence the type of fuel used.

In both models, the influence of household income on the selection of clean and efficient fuels for cooking is tangible (Heltberg, 2005). Household income and wealth have been found to be major determinants of cooking fuel selection in rural India (Bansal et al., 2013). Education is another important factor. In India, the number of educated women in the household has been shown to have a positive and significant influence on the use of clean fuels (Pandey & Chaubal, 2011). Similarly, Hanna et al (2016) observed that more than 93% of households in rural areas of Orissa, India, relied on traditional stoves and wood fuel and attributed this to low levels of welfare and education (especially among women).

3 Methodology

3.1 Description of data and variables

This study employs data from the Indonesia Family Life Survey-East (IFLS-East) 2012, which collected an abundance of information on the region's socio-economic characteristics (including age, education, access to health and education service, employment, asset, etc.) at the individual, household, and community levels (Satriawan et al., 2014). In the context of Eastern Indonesia, IFLS East is a multi-topic survey in Eastern Indonesia to date and modeled after IFLS.[1] In addition, it also included a community survey to collect information on villages' infrastructure, the health and education facilities utilized by households, and other community characteristics. The survey was designed to represent Eastern Indonesia, a less-developed part of the country where livelihoods and economic activities depend heavily on natural resources and capture a socio-economic portrait of households in the area. This study took as its sample 2547 households in seven provinces in Eastern Indonesia: East Kalimantan, North Maluku, Maluku, East Nusa Tenggara, Southeast Sulawesi, Papua, and West Papua (Fig. 1).

[1] https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS/ifls-east.html.

Table 1 Definition of variables

Categories	Variables
Household characteristics	Household fuel type: gas, kerosene, firewood
	Education of HH head (years of schooling)
	Age of HH head (years)
	Gender of HH head (1 = male)
	Household size (number)
	Source of livelihood (1 = farming)
	Per capita expenditures
	Urban (1 = urban)
	Electricity connection (1 = yes)
Community characteristics	Farmland (1 = yes)
	Forest (1 = yes)
	Village market
	Sub-district capital in the village (1 = yes)
	Price of kerosene

Information on energy choices for cooking was collected at the household level and obtained from the primary respondent (the head of the household, or a person 18 years or older who is able to answer the questions). Explanatory variables for multivariate analysis, including household and community characteristics, are presented in Table 1. For community characteristics, this study focuses on the presence of natural resources (i.e., forests) within the community.

3.2 Estimation strategy: the multivariate probit (MVP) model

A combination of descriptive and inferential analysis was used to analyze the IFLS-East dataset. Descriptive analysis was performed by cross-tabulating energy choices for cooking and selected explanatory variables (income, education, and location). For inferential analysis, this study identified three major energy sources for cooking (gas, kerosene, and firewood) and set them as dependent variables; a very small sample used electricity (5 of 2547 respondents) and charcoal (20 of 2547 respondents), which were merged with gas and firewood, respectively. Following Malla and Timilsina (2014) on the energy transition of cooking fuel, the choice of firewood, kerosene, and gas represents traditional, medium and modern fuel choice, respectively. The appropriate estimation strategy to analyze a dependent variable with multivariate binary outcomes is the multivariate probability model (MVP) (Golob & Regan, 2002; Edwards & Allenby, 2003). These choices were set as dependent variables (choice options). For each energy choice, the household had a binary choice, with 1 = use of a particular energy for cooking or 0 = otherwise. Following Mottaleb et al. (2017) and Ali et al. (2019), the choices of energy with three dependent variables, y_1, y_2, and y_3, were modeled such that:

$$y_i = 1 \text{ if } \beta_i X' + \varepsilon_i > 0$$

and

$$y_i = 0 \text{ if } \beta_i X' + \varepsilon_i \leq 0, \quad i = 1, 2, 3$$

where X is a set of explanatory variables (Table 1); β_1, β_2, β_3 are the vectors of the parameters of estimation, and ε_1, ε_2, ε_3 are random errors distributed with a multivariate normal distribution with zero mean and unitary variance.

Controlling for household and community characteristics, each type of household fuel choice is regressed separately as follows:

$$\begin{aligned} Y_{\text{im}} =& \alpha_0 + \alpha_1 \text{Educ}_{\text{im}} + \alpha_2 \text{Age Head}_{\text{im}} + \alpha_3 \text{Gender Head}_{\text{im}} + \alpha_4 \text{Gender Head}_{\text{im}} \\ &+ \alpha_5 \text{HHF arm}_{\text{im}} + \alpha_6 \ln \text{PCE}_{\text{im}} + \alpha_7 \text{Urban}_{\text{im}} + \alpha_8 \text{Electricity}_{\text{im}} + \alpha_9 \text{Farm land}_{\text{im}} \\ &+ \alpha_{10} \text{Forest}_{\text{im}} + \alpha_{11} \text{Village Market}_{\text{im}} + \alpha_{12} \text{Subdistrict Cap}_{\text{im}} + \propto_{13} \ln \text{Price Kerosene}_{\text{im}} + e_{\text{im}} \end{aligned}$$

where Y_{im} is a dependent variable. It assumes the value 1 when a household i uses gas for cooking, or 0 when otherwise; it assumes the value 1 when a household uses kerosene for the same purpose, or 0 when otherwise; it assumes the value 1 when a household uses firewood for cooking, or 0 when otherwise. M is the number of equations ($m = 3$, as households use three types of energy for cooking).

4 Results and discussion

4.1 Socio-economic characteristics of sample

From the total sample of 2547 households, the average age of the household heads was 44.39 years and the education completed (as measured by years of schooling) was 10 years (Table 2). These figures indicate that most of the household heads are in a productive age group and have a senior high school education. Table 2 also shows that sampled households mostly consisted of four to five family members (nuclear family) and were headed by male household heads (84%). About 65% of household heads engaged in farming activities as their main source of livelihood. Only about 30% of households live in urban areas. Of households surveyed, 83% reported that they have access to electricity; however, it was revealed that the use of electricity for cooking is very small (less than 1%). The mean per capita expenditure (PCE) is about IDR 997,748 (USD 70) per month. In terms of community characteristics, 34% of households reside in a village with a market; only 18% of households live in the sub-district capital. The mean kerosene price faced by the households was 9454.519 IDR (0.66 USD), which is relatively cheap due to government fuel subsidies. About 78% and 63% of households live in the village with forest cover and farmland, respectively. This finding indicates that most of the households in Eastern Indonesia are rural households in forest margin communities.

4.2 Household energy used for cooking

From the descriptive statistics (Tables 2 and 3), this study finds that almost 60% of the 2547 sampled households used firewood, more than 30% used kerosene, and only 10% used natural gas and LPG for cooking. As mentioned earlier, the cooking stoves in Indonesia depend on traditional fuels (firewood), medium fuels (kerosene) and modern fuels (gas). There have been several initiatives on the use of biogas (Singh & Setiawan, 2013), but the use of biogas is not evident in our sample. In terms of economic status, this study divides the household per capita expenditure as proxy for income into five groups and represents the economic status of the household. Disaggregated by income (Table 3 as indicated by income quintile), the energy choices for cooking indicated that

Table 2 Descriptive statistics of household characteristics and variables. *Source* Authors' calculation based on IFLS-East data

Variables	Stat	Total Samples ($N=2547$)	Std. dev
Household characteristics			
HH head education (years)	Mean	10.1	5.6
HH head age (years)	Mean	44.4	13.2
HH Head Livelihood (farm)	Frequency (%)	1645(64.6%)	
HH head gender (male)	Frequency (%)	2133(83.7%)	
HH size	Mean	4.3	2.1
Electricity	Frequency (%)	101(82.5%)	
Per capita expenditure (PCE) IDR		997,748	952017.5
lnPCE		13.5	0.8
Location (urban)	Frequency (%)	757(29.7)	
HH Energy for cooking			
Gas	Frequency (%)	258(10.1%)	
Kerosene	Frequency (%)	774(30.4%)	
Firewood	Frequency (%)	1478(58%)	
Community characteristics			
Market	Frequency (%)	866(34%)	
Sub-district office	Frequency (%)	460(18.1%)	
Village farmland	Frequency (%)	1621(63.6%)	
Village forest	Frequency (%)	1997(78.4%)	
Kerosene price (IDR)		9454.5	9164.4
ln_Kerosene price		8.8	0.7
$n=2547$			

the bottom-40 of households still depended highly on firewood; almost 90% of the poorest households use firewood for cooking, while only 1.8% and 8.9% of these households use gas and kerosene, respectively, for cooking. In contrast, 68% of the top-20 households use "cleaner" energy choices (gas and kerosene). This finding confirms that most rural poor households depend on firewood as their main cooking fuel. Only about 76% of households depending on firewood are electrified, which means that these households might also use lighting firewood. The dominance of firewood is supported by the availability of public forests where households can collect firewood; such a practice is common in developing countries, including in many parts of Indonesia (Budya & Arofat, 2011; Islam & Sato, 2012; Islam et al., 2014; Lee et al., 2015). A closer examination of the data (Table 3) shows that households using firewood for cooking tend to have larger household sizes and lower economic status (including lower education of household head and monthly per capita expenditures). In terms of location, only 5% of urban households depend on firewood as their energy source for cooking.

As indicated previously, households using cleaner energy sources, especially gas, are generally more affluent than those using other fuels, as indicated by their higher monthly per capita income (107.0 USD), higher level of education, smaller household size (less than 4 persons), and urban locations. Meanwhile, heads of households using gas for cooking generally received a higher level of education (secondary education,

Table 3 Energy choices for cooking by socio-economic characteristics and income. *Source* Authors' calculation based on IFLS-East data

	Gas	Kerosene	Firewood
Household characteristics			
HH Head Education (years, mean)	12.884	12.221	8.225
HH Head Age (years, mean)	43.647	43.152	45.233
HH Head Activity (working, %)	77.9	86.3	88.6
HH Head Gender (male, %)	77.9	81.7	85.7
HH Size (persons, mean)	3.829	4.109	4.471
Electricity access (electricity, %)	99.2	97	71.8
PCE IDR (in USD)	1,537,058 (107)	1,347,717 (93.8)	711,874.6 (49.55)
lnPCE	13.973	13.887	13.186
Urban (urban, %)	85.3	5.75	5.4
Income quintile			
Poorest (%)	1.8	8.9	89
2 (%)	5.9	18.6	75.5
3 (%)	9.8	32.2	58
4 (%)	15.8	42	43
Wealthiest (%)	16.4	51.7	28.9
N	258	774	1478

most frequently) than heads of households that did not. Almost all households using gas for cooking have an electricity connection.

4.3 Discussion

Based on MVP estimation, this study reveals that the education level of the household head, household source of livelihood, household size, and electricity connection are significant across all the three energy options for cooking (Table 4). The level of education of the household head is positively associated with the choice of gas and kerosene, while negatively affecting the use of firewood for cooking. The findings support former studies' findings regarding the importance of education (years of schooling) on the choice of cleaner energy sources. Better education leads to the use of cleaner energy choices through human capital increasing earnings which purchasing power enhancing and awareness of the health impact of indoor air pollution due to the use of traditional fuels (Alem et al., 2016; Rahut et al., 2020; Sambodo & Novandra, 2019). Education can also alter the value of time which leads to the use of saving time energy option.

In terms of source of livelihood, households engaged in farm activities are more likely to use firewood as a source of energy when cooking, while non-farm households are more likely to use kerosene or gas. Farm households utilized their agricultural residues, mainly woods, to meet their energy demand (Rahut et al., 2020, WHO 2006). Regarding household size, the coefficients for gas and firewood are negative and significant. While it is common for smaller households to use cleaner energy options, the negative association of household size on the choice for firewood seems to be counterintuitive and unlikely. This finding could be attributed to other factors, such as income, education, price of fuel,

Table 4 Regression results. *Source* Authors' calculation based on IFLS East 2012

	Gas	Kerosene	Firewood
Household characteristics			
HH head education (years)	0.028*** (0.009)	0.013*** (0.006)	−0.030*** (0.007)
HH head age (years)	0.008*** (0.004)	−0.002 (0.003)	−0.001 (0.003)
HH head gender (dummy, male = 1)	−0.176 (0.117)	−0.063 (0.090)	0.212*** (0.104)
HH Farm (dummy, farm household = 1)	−0.877*** (0.110)	−0.880*** (0.074)	1.377*** (0.079)
Electricity (dummy, yes = 1)	1.073*** (0.275)	0.573*** (0.122)	−0.722*** (0.115)
HH size (numbers)	−0.014*** (0.027)	0.063*** (0.018)	−0.053*** (0.019)
lnPCE	0.115 (0.074)	0.483*** (0.052)	−0.679*** (0.058)
Community characteristics			
Market (dummy, village market = 1)	0.843*** (0.098)	−0.178*** (0.071)	−0.375*** (0.078)
Sub-district office (dummy, sub-district office = 1)	−0.198* (0.116)	−0.030 (0.084)	0.157 (0.096)
Village farmland (dummy, farmland = 1)	0.283** (0.100)	−0.267*** (0.069)	0.255*** (0.076)
Village forest (dummy, forest = 1)	−0.166 (0.107)	−0.217*** (0.084)	0.553*** (0.102)
ln_Keroseneprice	0.746*** (0.069)	−0.447*** (0.055)	0.119*** (0.059)
Wald	474.690	721.680	1357.860
Pseudo *R*	0.323	0.257	0.444
N	2547		

Standard errors are shown in parentheses

*Denotes statistical significance at 10%

**Denotes statistical significance at 5%

***Denotes statistical significance at 1%

livelihood strategies, access to markets and natural resources, which may contribute more to the choice of energy for cooking (Wassie et al., 2021). On the other hand, household size significantly and positively influences the choice of kerosene. In line with the existing literature (Miah et al., 2011; Ouedraogo, 2006), electricity connection is a significant determinant, being significantly and positively associated with gas and kerosene usage. This finding indicates a complementarity between electricity and cleaner household energy sources.

Other household demographic characteristics such as gender and age also play a role in household energy choice. The gender and age of the household head are insignificant for gas and kerosene, but positive and significant for firewood. This finding confirms the existing literature that male-headed households tend to use dirty energy sources (Berhe et al., 2017; Rahut et al., 2017). Income is one of the key variables in households' choice of energy, as stated in the energy ladder model. This study revealed that household per capita expenditure (which represents household income) is significant for kerosene and firewood but insignificant for gas. The positive and significant sign of per capita expenditure on kerosene option suggests that middle-income households are more likely to use "cleaner" fuel sources than poorer households, which are more likely to use firewood. On the other hand, per capita expenditure is insignificant for households who already use clean energy sources for cooking, as they already at the highest rung of the ladder. Moving up the energy ladder

through the use of modern fuels increases energy efficiency and reduces emissions. The findings of this study underscore the vital role of income in choosing an energy source for cooking in less developed areas (Rahut et al., 2019; Ali et al., 2019; Guta, 2014). To really enhance the role of income, a thorough understanding on the development context in Eastern Indonesia is important. With the average income per capita 997,748 IDR (69.5 USD) per month, household economic capacity is relatively lower to the Western Indonesia's average, 1,403,098 (97.6 USD).[2] This income disparity leads to gap in various access including access and choices in energy. The disparity in access to electricity and energy might be attributed to income disparity across region (Cahyani et al., 2020; Thoday et al., 2018).

This study also examined the role of community characteristics, as represented by the availability of infrastructure (market and sub-district government offices) in the village, in households' choices of energy for cooking. Market access in the village has a positive and significant effect on the choice of gas for cooking. In an Indonesian context, LPG is distributed to households and small-medium-enterprises through official agents, sub-agents, and retailers. Typically, agents and sub-agents are the owners of local convenience shops or kiosks who sell LPG to consumers, most of whom are located near the village market or offices (World Bank, 2013). Access to the official distributors selling the official subsidized price of LPG is limited in rural and remote areas, and sometimes poor households need to pay additional transport costs (Kuehl et al., 2021). Having the context of limited infrastructure in the Eastern Indonesia, household income might not play as a single determinant to switch energy sources from firewood to LPG. The government's major challenge in the LPG distribution is to reach the remote locations where the vast majority of poor households are located. Improving both targeting and distribution particularly in rural Eastern Indonesia is among the biggest homework of the government in energy subsidy reform.

The presence of natural resources (i.e., shared forests and farmland) in the village was also examined. The presence of natural resources in a community plays a key role in household energy choice. Households in villages with expansive shared forests and farmland tend to rely on kerosene and firewood, as the presence of nearby forests reduces the costs incurred when collecting firewood. In line with previous studies, reliance on firewood for cooking energy in forest-margin communities (mostly poor residents) may drive deforestation and forest degradation (Lee et al., 2015; Mottaleb et al., 2017). Hence, the findings of this study contribute to the debate on the energy-environment-health issues and show that the poor households in nearby forests and farm land rely on firewood and they are potentially exposed to indoor air pollution.

In terms of price of kerosene, this study follows Lim et al (2021) in estimating the energy demand and transforms the kerosene price in the log form to investigate the estimate for the price elasticity. This study also finds that the increased price of kerosene corresponds with the principles of supply and demand; as a coefficient, kerosene prices are negative and significant for kerosene usage, but positive and significant for gas and firewood usage. This finding indicates that as the price of kerosene increases, richer households tend to switch to gas; lower-income households, meanwhile, choose to use firewood. These findings emphasize the important role of government policy on price stability and subsidies in Indonesia.

The findings of this study emphasized the connection of income, market, energy prices, and natural resources. Poor households in rural and remote areas, especially in Eastern Indonesia, are vulnerable to energy poverty, and they are poor household without access to

[2] Indonesia Bureau of Statistics (2019).

clean cooking fuel. In the case of Indonesia, as subsidized LPG remains facing challenge, other initiative was launched in early 2012 introducing clean cook stoves for households that had not converted to LPG (World Bank, 2014). Similar to the kerosene to LPG conversion program, increasing demand for clean stoves needs to be accompanied by public health campaign. Public education about the characteristics and benefits of using modern and high-quality stoves can drive practices and adoption of clean energy choice for cooking.

5 Conclusion and implications

To reduce the use of dirty fuel and to encourage and enhance the use of clean and high-quality energy sources, it is necessary to understand the factors that determine a household's energy choices. Using Eastern Indonesia, a lagging area rich in natural resources, as a case study, this study identifies important factors that determine households' choice and dependence on different types of energy. This study reveals that affluent households and households with better socio-economic indicators (including higher education, non-farm livelihoods, smaller sizes, and electricity connectivity) tend to use clean energy sources for cooking. Households located in urban areas, closer to markets, tend to rely more on gas as a source of cooking energy. In contrast, poorer rural households in villages with abundant natural resources (i.e., where villages have expansive forests and farmlands) generally use firewood as their main source of energy for cooking. The findings of this research also show that energy prices contribute significantly to the choice of clean and dirty fuel for cooking.

The findings from this study suggested that efforts to enhance households' use of clean energy also consider improving their economic status (especially income and education), providing access to markets, and ensuring stable energy prices. Investment in education can enhance human capital, which in turn can reduce households' dependency on dirty fuel by increasing income and awareness of health impacts of traditional fuels. Finally, policy interventions that account for energy and environment issues need to be designed to reduce dependence on firewood for cooking energy in households living near common property resources.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The paper is based on data analysis of publicly available secondary data-set. The survey and its procedures have been reviewed and approved by Institutional Review Boards (IRBs) in Indonesia.

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