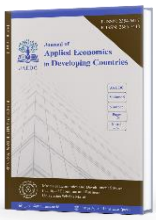

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THE IMPACT OF LIQUEFIED PETROLEUM GAS CONVERSION ON WOMEN'S ACTIVITY

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ABSTRACT

This study examines the impact of Liquefied Petroleum Gas (LPG) conversion on women's empowerment indicated by married women's economic and social activity. LPG conversion is the biggest program for switching kerosene to LPG in Indonesia. This study uses work hours as a proxy for economic activity and the number of social gatherings as a proxy for social activity. The difference-in-difference method was used as the research method. The 4th and 5th wave data from the Indonesian Family Life Survey (IFLS) were used as the research data. The examination of married women was conducted in the analysis unit. Estimation of regional and demographic sub-samples was also performed to determine which received greater impact. Based on the estimation results, it is found that the LPG conversion can increase the work hours of average women by 209.64 hours/year or 4.03 hours/week and the number of social gatherings by 0.14. The sub-sample estimation also confirms that the impact of LPG conversion still has a positive causal effect on the two variables of interest. This paper adds to the existing literature by using the more comprehensive causal effect of using clean energy on women's empowerment, being the first study to analyze the impact of the LPG conversion program on women's economic and social activity.

1. INTRODUCTION

Energy is an important element in development, both macro, and micro. In the context of implementation at the household level, experts from various fields have designed the Sustainable Development Goals 2030 as the seventh target. The targets are designed to assure access to affordable, reliable, sustainable, and modern energy for humans. Modern energy is familiar with clean energy. Clean energy is defined as the use of environmentally friendly energy, such as electrification and clean cooking energy (use LPG). The use of modern energy offers numerous benefits, including increased individual productivity, improved room temperature control, enhanced transportation for work and school, better utilization of free time, and the fulfillment of various rights. Access to modern energy significantly impacts individual development. Conversely, the absence of such access can result in 1) reduced productivity; 2) limited job opportunities; and 3) reliance on wood or biomass, which adversely affects both human health and the environment.

According to International Energy Agency (IEA) (2024), approximately 2.1 million people die annually due to diseases caused by inefficient fuel use. Limited access to clean energy remains a pressing issue. IEA also highlights that over 2.6 billion people worldwide lack access to clean cooking solutions, often relying on inefficient stoves or open fires in poorly ventilated environments. Several interventions were established to encourage clean cooking energy. Indonesia is a pioneer country intervening in shifting the use of kerosene to Petroleum Gas (LPG) on a large scale. The intervention of use began at the end of 2007 to 2013 in stages in several regions. The main reason for implementing this LPG conversion program is to reduce energy subsidies (Budya & Arofat, 2011).

Before the conversion program in 2006 and 2007, the kerosene subsidy was 57% and 48% of total state subsidies were allocated for petroleum products. The Indonesian government in the effort of reducing this fiscal burden has reallocated the subsidy from kerosene to 3 kg LPG. Based on BPS data (2019), during the two years (2008-2010), the use of kerosene decreased by 18.78% bps. In less than six years since the program started, PT. Pertamina (as the distributor) has distributed LPG kits to nearly 54 million households and small-medium enterprises, or 93% of the target (Dartanto et al., 2020).

In addition to fiscal issues as the main focus of the LPG conversion program, this program can also extend its benefits to women's empowerment through better time allocation. These benefits are: 1) eliminating time and effort to collect biomass oil; and 2) reducing the effort devoted to cooking and cleaning (Smith et al., 2005). Based on Becker (1965) theory of time allocation, time allocation refers to the distribution of an individual's available time across various activities, including work, household production, and leisure. This theory serves as the foundation of this study, as it provides a framework for understanding how individuals, particularly women, allocate their time in response to external factors such as LPG conversion. By applying Becker's model, this research examines how changes in household production—specifically the shift from traditional fuel to LPG—affect women's time allocation, potentially influencing their participation in economic and social activities.

This requires women to consider the distribution of their time between household production, labor market work, and leisure in order to maximize their utility. In household production, based on Berk (1985) (see in (Fauser, 2019)) defines food preparation, cleaning, and washing as routine responsibilities of women. These continuous duties persist across nearly all cultures, particularly among married women. Parikh (2011) analyzed the lost time opportunity for women's working time in Sri Lanka due to biomass fuel collection. The results showed that the hours lost were about 2.7 hours per trip per day.

The use of LPG same as the context of time-saving technology. It can reduce household production time, especially cooking (Brenčič & Young, 2009; Smith et al., 2005). Therefore, it can reduce the workload and expand the time of women. Some literature shows a positive relationship between the use of household technology saving the time by cutting household production time to a reallocation of time for other activities (Brenčič & Young, 2009; Coen-Pirani et al., 2010; Fang & Zhu, 2017; Omotoso & Obembe, 2016; Rupert et al., 1995).

The reallocation of women's time can be used to explore their abilities to take economic opportunities more broadly in social life. Women, especially those who are married, can take advantage of these opportunities to increase working hours and increase social capital. Increasing the time spent working or socializing can increase women's empowerment, especially married women. This can provide an opportunity to have a larger influence on household decisions and to reduce abuse in the household.

In this study, there are two important reasons to find out more about the causal effect of LPG conversion on women's economic and social activity. First, the success of the Indonesia's LPG program is often underestimated in cost-benefit analysis focused solely on subsidy savings. Evaluating the impact on time savings could improve the cost-benefit ratio. There has not been any study about the impact evaluation of the LPG conversion program approaching women's empowerment. Existing impact evaluation focus on energy poverty in Indonesia (Andadari et al., 2014), the positive impact of LPG conversion on the environment (emissions)

(Kurniawan et al., 2018; Permadi et al., 2017; Rosenthal et al., 2018), and a causal relationship from fuel switching to infant mortality (Imelda, 2018). Second, women have historically specialized in home production. Especially for married women in terms of time allocation, they tend to reduce their working hours and increase household production (Gronau, 1977), notes women's routine tasks like cooking and cleaning, contrasted with men's less frequent maintenance and repair, creating a gap in men's and women's average working/leisure time (Fauser, 2019). On other hand, men have tasks such as maintenance, home, and vehicle repairs which are not done all the time. This results in a large gap in the average amount of working or leisure time enjoyed by women and men. In some literature studying the time allocation for couple workers, statistics show that women continue to do, a greater proportion of household chores and childcare than their male partners (García-Mainar et al., 2011; Hwang et al., 2019; Sevilla-Sanz et al., 2010). In other words, an increase in working hours due to a decrease in household production will minimize or negate the impact of changes in household production time and leisure time.

An increase in reallocation time can also stimulate women's opportunities for women's work participation. Indonesia has for two decades experienced stagnation in women's labor participation rates. In 2016, women's labor force participation in Indonesia reached 50.9% and did not develop significantly from the participation rate of 50.2% in 1990 (Cameron et al., 2019; Halim et al., 2017; Schaner & Das, 2016). Traditional roles in the family, responsibility towards children, and cultural norms are the root inhibitors of Female Labor Force Participation (FLFP) (Jayachandran, 2015). Several studies have identified the drivers and barriers to the supply of female labor in Indonesia, including education and wealth (Schaner & Das, 2016), spouse's wage (Klasen et al., 2020), and childcare (Cameron et al., 2019; Halim et al., 2017; Schaner & Das, 2016). Based on those various kinds of literature, no one has discussed the inhibiting factors of responsibility at home such as cooking. Therefore, this research is highly important to be conducted to expand the derivation of Female Labor Force Participation (FLFP) in Indonesia.

Meanwhile, Aguiar & Hurst (2007) and Cruz & Raurich (2020) using time survey data, successfully demonstrates a trend of increasing working hours, which sequentially leads to higher income and subsequently results in an increase in leisure time. Aguiar & Hurst (2007) argue that what distinction between "free time" and "working time" is a matter of perception as leisure activities can increase generate utility similar to working time by increasing knowledge or serving as a substitute for market time. Aguiar et al. (2013) further defines one dimension of the relationship between leisure and work as complementary, influenced not by the content or form of work but by social roles and the need for job compensation. This relationship is particularly evident in social networking activities, where leisure time is socially determined through its connection to employment status. According to Łopaciuk-Gonczaryk (2019), social networks are fundamental in shaping trust and cooperative behavior, implying that well-established collaborations in the past and present can create opportunities for future cooperation. Forms of social networks in Indonesia include formal institutions, such as LPMD, PKK, Karang Taruna, Dharmawanita, and Dasawisma, and informal ones, such as social gatherings.

Based on the two compelling reasons outlined above, the gaps in knowledge regarding the impact of successful LPG conversion on the women's empowerment pathway are expected to be filled in. This study exploits the benefits of access to clean cooking energy to conclude the causal effect of LPG conversion on the reallocation of proxied women's time to economic and social activity using the difference-in-difference method. The unit of analysis in this study is married women. The welfare indicator used in this study is women's time for economic and social activity.

2. RESEARCH METHODS

The data used in this study come from the 4th wave of IFLS (IFLS 4), which captures women's economic and social activities before government intervention in 2007, and the 5th wave of IFLS (IFLS 5), which reflects conditions after government intervention in 2014. This period is highly appropriate for examining the conditions before and after the LPG conversion program, which was implemented between late 2007 and 2013.

The unit of analysis in this study is married women in 2007 and 2014. Since IFLS does not provide comprehensive information on individual time allocation, work hours are used as a proxy for economic activity, while social gatherings (referred to as *arisan* in Indonesia) serve as a proxy for social activity. Work hours and social gatherings are the dependent variables in this study. To ensure consistency in information for each individual before and after the program, a balanced panel data approach is emphasized. As a result, to maintain sample size and data consistency for each dependent variable, two separate datasets are used. This study aims to analyze the impact of LPG conversion on women's economic and social activities, using work hours and the number of social gatherings as dependent variables. To ensure validity, a balanced panel data approach is applied, requiring separate datasets for each dependent variable.

Table 1 presents the number of LPG users based on the year of observation for the dataset estimating the impact of LPG conversion on work hours. The total number of observations includes 8,784 married women in a panel dataset, representing 4,392 married women per year. In 2007, non-LPG users dominated the sample, with approximately 85% of total annual observations not using LPG. By 2014, this figure had declined to around 35%, indicating a 50 percentage-point increase in LPG adoption.

Table 1. Number of LPG Users on Economic Activity Analysis

LPG	Year		Total
	2007	2014	
Non- LPG users	3,732	1,524	5,256
LPG users	660	2,868	3,528
Total	4,392	4,392	8,784

Source: IFLS 4 dan IFLS 5 (calculated)

Table 2 presents the number of LPG users based on the year of observation for the dataset estimating the impact of LPG conversion on social gatherings. The total number of observations includes 17,698 married women in a panel dataset, representing 8,849 married women per year. Between 2007 and 2014, LPG usage increased by approximately 55 percentage points. Based on Table 1 and Table 2, the IFLS data successfully capture the LPG conversion program. Therefore, the use of these two datasets does not compromise the validity of the impact evaluation of LPG conversion in this study.

Table 2. Number of LPG Users on Economic Activity Analysis

LPG	Year		Total
	2007	2014	
Non- LPG users	7,403	2,571	9,974
LPG users	1,446	6,278	7,724
Total	8,849	8,849	17,698

Source: IFLS 4 dan IFLS 5 (calculated)

The method used is Difference in Difference (DID) method. This method is a quasi-experimental design utilizing panel data from the treatment group and the control group. The use of panel data to solve data loss problems illustrates the comparison of conditions in groups before and after the program so that the counterfactual matter is suitable for estimating causal effects. DID evaluates the impact of government programs or policy interventions by comparing the differences in outcomes before and after for the treatment group with the same differences for the untreated group.

A simple implementation of the DID method is to use two time periods (before and after) and two groups (treated and control). The DID equation is shown below:

$$DD = E(Y_{1,t=1} - Y_{1,t=0} \mid CE = 1) - E(Y_{0,t=1} - Y_{0,t=0} \mid CE = 0) \quad \text{..... (1)}$$

Description:
CE = 1 : indicates the individual using clean cooking energy
CE = 0 : indicates the other
Y_1 : the resulting outcome for individuals in the treated group
Y_0 : the resulting outcome for individuals in the untreated group
t : the period before (t = 0) and after the program year (t = 1).

The econometric model for DID is shown below:

$$(Y_{it}) = \beta_0 + \beta_1 t_i + \beta_2 CE_{it} + \beta_3 t_i . CE_{it} + \varepsilon_{it} \quad \text{.....(2)}$$

Description:
t_i : a dummy variable, '1' for year = 2014 and '0' for year = 2007
Y_{it} : the number of hours worked by women or the number of social gatherings attended by women in year t.
CE_{it} : the dummy variable, '1' for cooking using electricity and LPG, and '0' for others in year t.
β_3 : the interaction between the program (CE_{it}) and time (t) give the average DID impact of the program.

The empirical model for DID estimation is to use the Fixed Effect Model Panel. The use of the model makes it possible to control not only for unobservable time-invariant characteristics of heterogeneity but also for characteristics of time-variance heterogeneity. Y_{it} can be regressed at CE_{it} , time-varying variable (X_{it}), time-non-variable individual heterogeneity (η_i) and unobserved characteristics (ε_{it}). Hence, the DID equation by considering the revised equation (2) is as follows:

$$(Y_{it}) = \beta_0 + \beta_1 t + \beta_2 CE_{it} + \beta_3 t . CE_{it} + \beta_4 X_{it} + \beta_5 \eta_i + \varepsilon_{it} \quad \text{.....(3)}$$

X_{it} is the control variable changing over time and including individual characteristics, family head characteristics, household characteristics, household welfare characteristics, and demographic. In estimating the number of social gatherings, control variables were added, such as trust, community participation, and cooperative membership participation. Differentiation of the right and left sides of the equation (3) from time to time, will get the following differential equation:

$$(Y_{it} - Y_{it-1}) = \beta_1 (CE_{it} - CE_{it-1}) + \beta_2 (X_{it} - X_{it-1}) + \beta_3 (\eta_i - \eta_i) + (\varepsilon_{it} - \varepsilon_{it-1}) \quad \text{.....(4)}$$

$$\Leftrightarrow (\Delta Y_{it}) = \beta_1 \Delta CE_{it} + \beta_2 \Delta X_{it} + \Delta \varepsilon_{it} \quad \text{.....(5)}$$

In this case, since the source of endogeneity (i.e., unobserved individual characteristics) is dropped from difference, Ordinary Least Squares (OLS) to equation (5) can be used to estimate the unbiased effect of the program β_1. Using the two time periods, (β_1) is equivalent to the estimate of DiD in equation (3), using the same covariate X_{it}. The variables used in econometric estimation are shown in Table 3.

Table 3. Description of Variables

Variables	Description	
Dependent Variables		
Work hours	The economic activity of the respondent	Number of work hours in a year
Social gathering (Sosgath)	Social activity of the respondent	Number of social gathering in a year
Independent Variable		
Clean energy	A dummy variable representing the choice of the cooking fuel	1 if yes for using LPG and electric, and 0 otherwise

Control Variable		
Individual Characteristic		
Age	Age of the respondent	Years
Education	Years education of the respondent	Years
Work status	A dummy variable representing the work status of the respondent	1 if the respondent has a job and 0 otherwise
Work specialization	A dummy variable representing the work specialization of the respondent	1 if the respondent has a job in the formal sector and 0 if the respondent has a job in the informal sector.
Head of Household Characteristic		
Age	Age of the head of the household	Years
Education	Years education of the head of the household	Years
Sex	Sex of head of the household	1 if male and 0 if female
Household Characteristic		
Toddler	Number of children aged 0-5 years	
Children	Number of children aged 0-5 years	
HH Number	Number of the household members after subtracting the number of children and respondent	
Wealth Characteristic		
Ventilation	A dummy variable representing that the house occupied has adequate ventilation	1 if the house has ventilation, 0 otherwise
Rooms	Number of rooms	
Equipment	Number of household's equipment	Home appliances include televisions, radios, tapes, refrigerators, cell phones, sewing machines, washing machines, computers, and VCDs
Kitchen	A dummy variable representing that the cooking room blends with the bedroom	1 if yes and 0 otherwise
Electricity	A dummy variable representing the respondent's house has electricity	1 if yes has electricity and 0 other
Water	Distance from individual houses to drinking water sources	Meters
Agriculture	A dummy variable representing the household is an agricultural household	1 if an agricultural household and 0 otherwise
Recreation	Share of household recreation expenditure	Rupiah
Other Social Capital		
Trust	Index trust representing	
Norm	Index norm represents willingness respondent to help color in this village if needed	
Cooperative	Community participation in the form of cooperatives in all types of cooperatives and at all levels: Dasa Wisma, RT, RW, Village, or District	1 if participating and 0 otherwise
Community gathering	Community participation in the form of community gatherings in all types of cooperatives and at all levels: Dasa Wisma, RT, RW, Village, or District	1 if participating and 0 otherwise
PKK	Women participation in Family Empowerment and Welfare organizations	1 if participating and 0 otherwise
Demographic		
Urban-rural	A dummy variable representing demography	1 if respondent living in urban and 0 other

3. RESULTS AND DISCUSSION

3.1. RESULTS

Descriptive analysis provides an initial overview of the variables used in the study and aims to understand the characteristics of the data before estimating the impact of LPG conversion on women's economic and social activities. Through this analysis, initial patterns of change before and after the LPG conversion program can be identified, providing a stronger foundation for interpreting the estimation results.

Table 4. Number of LPG Users by Subsample

Sample Description		Sub set data Dependen = Working Hours			Sub set data Dependen = Social Activity		
		Year		Total	Year		Total
		2007	2014		2007	2014	
All sample	Non-LPG Users	3,744	1,529	5,273	7,454	2,590	10,044
	LPG Users	665	2,880	3,545	1,459	6,323	7,782
	Total	4,409	4,409	8,818	8,913	8,913	17,826
Urban Areas	Non-LPG Users	1,426	413	1,839	3,173	787	3,960
	LPG Users	506	1,848	2,354	1,161	4,253	5,414
	Total	1,932	2,261	4,193	4,334	5,040	9,374
Rural Areas	Non-LPG Users	2,318	1,116	3,434	4,281	1,803	6,084
	LPG Users	159	1,032	1,191	298	2,070	2,368
	Total	2,477	2,148	4,625	4,579	3,873	8,452
Java	Non-LPG Users	1,979	670	2,649	4,071	1,144	5,215
	LPG Users	454	1,757	2,211	1,015	3,932	4,947
	Total	2,433	2,427	4,860	5,086	5,076	10,162
Outside Java	Non-LPG Users	1,765	859	2,624	3,383	1,446	4,829
	LPG Users	211	1,123	1,334	444	2,391	2,835
	Total	1,976	1,982	3,958	3,827	3,837	7,664

Source: Processed Data (2024)

Table 4 presents data on LPG and non-LPG users across different subsamples for two dependent variables: working hours and social activity, based on data from the years 2007 and 2014. The overall trend shows a significant increase in LPG users over time, accompanied by a decline in non-LPG users, indicating the success of the LPG conversion program. In the total sample, the number of LPG users rose from 665 in 2007 to 2,880 in 2014 for the working hours dataset and from 1,459 to 6,323 for the social activity dataset.

A closer look at urban and rural areas reveals that urban regions experienced a more substantial increase in LPG users, with numbers rising from 506 to 1,848 (working hours) and from 1,161 to 4,253 (social activity). In contrast, rural areas showed a slower but noticeable increase, with LPG users growing from 159 to 1,032 (working hours) and from 298 to 2,070 (social activity). This suggests that urban households adopted LPG more rapidly compared to rural households, possibly due to better infrastructure and accessibility.

Similarly, when comparing Java and outside Java, both regions exhibit a consistent upward trend in LPG users, though Java shows a more substantial increase. In Java, LPG users grew from 454 to 1,757 (working hours) and from 1,011 to 3,892 (social activity), while outside Java, the increase was from 211 to 1,123 (working hours) and from 444 to 2,391 (social activity). These differences may be attributed to varying levels of government support, infrastructure, and awareness campaigns in different regions.

Overall, the data highlights a clear shift from non-LPG to LPG usage across all demographic groups, with urban areas and Java experiencing the fastest adoption. This transition provides a strong basis for further analysis of how LPG conversion has influenced women's economic and social activities over time.

The initial analysis was conducted to ensure that the two analyzed variables followed a similar general trend. In the Difference-in-Differences (DID) method, an assumption is required regarding how the dynamics of the control and treatment groups evolve over time. The assumption used is the "common trend", which means that in the absence of an intervention or program, the average change in the outcome variable would be the same for both the treatment and control groups. In other words, without the program, the difference between the two groups would remain constant over time.

This analysis utilizes two waves of the IFLS survey to represent conditions before and after the intervention. Figures 1 and 2 support this assumption by showing the average trends in working hours and the frequency of social gatherings attended by married women before and after the LPG conversion. A visual inspection of Figure 1 reveals that before the LPG conversion, the number of working hours for married women exhibited an upward trend (an upward slope). This could introduce potential bias in causal interpretation if not properly accounted for. However, this trend also clarifies that the upward slope was already present before the program started. After the LPG conversion, there was a significant decline in working hours for married women who did not switch to LPG. In other words, this pattern suggests that the LPG conversion program may have influenced the dynamics of women's working time and social activities, which requires further analysis using a more rigorous causal approach.

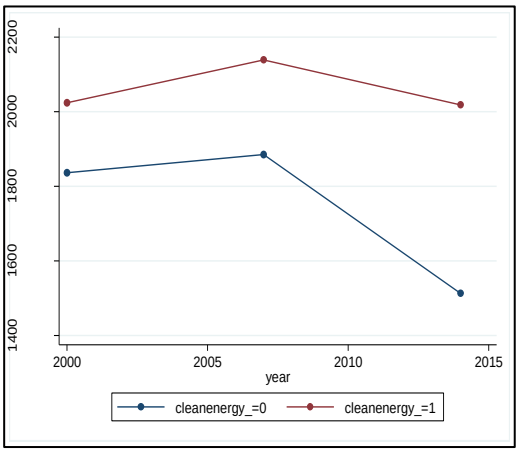

Figure 1. Common Trend in Women's working hours Estimation
Source: IFLS 3, IFLS 4, and IFLS 5 (processed)

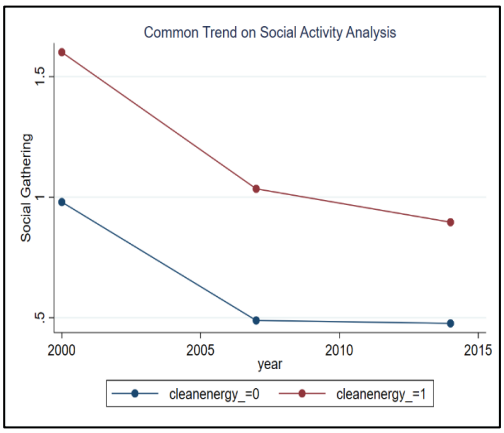

Figure 2. Common Trend on Social Activity Analysis
Source: IFLS 3, IFLS 4, and IFLS 5 (calculated)

The evaluation used the DID method with the First Difference estimates model. The model estimation will be carried out separately between economic activity and social activity. The use of First Difference estimation aims to control the time-invariant and unobserved variables that can cause bias in individual characteristics (see equation (5)). There is no test to prove the loss of the bias results. Only arguments and robustness checks create credibility for estimation results.

For robustness check, the first model is estimation without control variables and models. In subsequent models, the control variables are gradually added based on several categories. These categories are individual characteristics, family head characteristics, household characteristics, household welfare characteristics, and demographic. A control variable is added for estimating social activity, namely other social capital. Besides, the sub-sample for robustness check is also included in the estimation.

Table 5 presents the estimation results, where the dependent variable is women's work hours in a continous form. Model 1 reports the basline regression using first difference estimates without control variables. The clean-energy variable has coeficient of 216.45 hours per year, or approximately 4.16 hours per week (assuming a 52-week year). When control variables are incorporated (see Table 5, Models 2 to 6), the estimation results remain consistent, confirming the significant positive impact of LPG conversion. The coefficient slightly adjusts to 209.64, still significant at the 1% level, indicating that LPG conversion increases women's average work hours by 4.03 hours per week.

Table 5. First Difference Model Estimation Results on Economic Activity

	(1) Work Hours	(2) Work Hours	(3) Work Hours	(4) Work Hours	(5) Work Hours	(6) Work Hours
Clean energy	216.45***	208.84***	213.38***	208.33***	208.92***	209.64***
	(53.034)	(52.473)	(52.518)	(52.911)	(54.471)	(54.446)
Individu	No	Yes	Yes	Yes	Yes	Yes
Head Household	No	No	Yes	Yes	Yes	Yes
Household	No	No	No	Yes	Yes	Yes
Wealth	No	No	No	No	Yes	Yes
Urban rural	No	No	No	No	No	Yes
N	3,732	3,732	3,732	3,732	3,732	3,732
r2_a	0.004	0.029	0.029	0.032	0.033	0.032
p	0.000	0.000	0.000	0.000	0.000	0.000

Source: Processed Data (2024)
Note: The numbers in parentheses are the Standard Error (SE) adjusted in id
*** = 1% significance level, ** = 5% significance level, * = 10% significance level

To further examine variations in this impact, Table 6 provides a subsample analysis using the first-difference model, distinguishing between rural and urban areas. The results reveal that the magnitude of the impact is greater in rural areas than in urban areas. Specifically: 1) In rural areas, LPG conversion leads to an increase of 4.29 work hours per week, with a highly significant p-value of 1%.; and 2) In urban areas, the increase is 3.83 work hours per week, with a p-value of 5%, indicating a slightly weaker but still significant effect.

This breakdown highlights the importance of regional context in determining the effect of LPG conversion. The stronger impact in rural areas may stem from greater initial reliance on traditional fuels, leading to more significant time savings after conversion. In contrast, urban households may have already had better access to alternative cooking technologies, resulting in a comparatively smaller increase in work hours. By presenting both overall and subsample analyses, these findings provide a more comprehensive and connected understanding of how LPG conversion influences women's labor allocation across different settings.

The difference in the participation between women in rural and urban work is partly related to women's participation in unpaid (Tanaka & Muzones, 2016). Besides, in this sub-sample, the rural population using non-LPG is greater than the urban population. It may be due to the easier access that rural residents prefer to use wood or biomass fuels. Most people in rural areas combine kerosene with other energies, whereas urban areas rely on it as a single source for cooking (Andadari et al., 2014). On the other hand, the use of wood or biomass fuels causes the loss of longer cooking time. Therefore, the conversion can save a long time for rural women.

Furthermore, the women living outside Java Island received greater benefits than those living in Java based on the results in the sub-sample of Java and non-Java. The LPG conversion gave a greater positive impact for women in non-Java than for those in Java. In non-Java, the average women's work hours have increased by 4.58 hours/week with the significance of the p-value of 1%. Meanwhile, the average women's work hours in Java have increased by 2.61 hours/week with the significance of the p-value of 10%.

Table 6. First Difference Model Estimation Results on Economic Activity with Sub-samples

	(1) Work Hours	(2) Work Hours	(3) Work Hours	(4) Work Hours	(5) Work Hours	(6) Work Hours	(7) Work Hours
Clean energy	209.64***	199.40**	223.03***	135.71*	257.96***	46.60	247.54***
	(54.446)	(89.860)	(70.366)	(73.216)	(79.822)	(114.515)	(65.658)
Individu	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Head Household	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wealth	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Urban rural	Yes	No	No	Yes	Yes	Yes	Yes
N	3,732	1,738	1,994	1,965	1,767	947	2,785
r2_a	0.032	0.040	0.026	0.032	0.030	0.037	0.004
p	0.000	0.000	0.000	0.000	0.000	0.000	0.023

Source: Processed Data (2024)

Note: The numbers in parentheses are the Standard Error (SE) adjusted in id

*** = 1% significance level, ** = 5% significance level, * = 10% significance level

Model (1) show the results of all samples, Model (2) show the results for the sample in urban area, Model (3) show the results for the sample in rural area, Model (4) show the results for the sample in Java Island, Model (5) show the results for the sample in rural Non-Java Island, Model (6) show the results for the sample who works in formal sector, and Model (7) show the results for the sample who works in informal sector.

In the work sector, the average impact of LPG conversion is higher for informal workers. The impact of LPG conversion in the informal sector can increase the working hours by 4.76 hours/week with a significant p-value of 5%. The different impacts in the formal sector, working hours have increased by 0.90 hours/week. The result shows the same results as the research conducted by Halim et al. (2017) estimating the impact of pre-school on the participation of women to work in Indonesia, namely that the presence of pre-school only had an impact on women having jobs in the informal sector. Halim et al. (2017) argue that this was because working time in informal jobs was more flexible than formal workers. Overall, the DID analysis shows the positive impact of LPG conversion on increasing women's work hours. These results support time allocation theory research, namely that a reduction in household production will increase women's productivity (Coen-Pirani et al., 2010; Fang & Zhu, 2017; Gronau, 1977; Rupert et al., 1995).

Table 7 presents the estimation results of the first-difference model, focusing on the impact of LPG conversion on women's participation in social gatherings. Model 1 reports the baseline regression results without control variables, showing that the clean-energy variable has a coefficient of 0.16, which is statistically significant at the 1% level. This indicates that LPG conversion is associated with an increase in the number of social gatherings attended by women.

Across all model specifications (Models 1 to 7), the results remain consistent and significant at a p-value below 1%, confirming the positive effect of LPG conversion on social participation. In the fully controlled model (Model 7), the coefficient is 0.14, meaning that LPG conversion leads to an average increase of 0.13 social gatherings for women, maintaining a high level of statistical significance.

Table 7. First Difference Model Estimation Results on Social Activity

	(1) Socgath	(2) Socgath	(3) Socgath	(4) Socgath	(5) Socgath	(6) Socgath	(7) Socgath
Clean energy	0.16***	0.16***	0.15***	0.15***	0.14***	0.14***	0.14***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
Individu	No	Yes	Yes	Yes	Yes	Yes	Yes
Head Household	No	No	Yes	Yes	Yes	Yes	Yes
Household	No	No	No	Yes	Yes	Yes	Yes
Wealth	No	No	No	No	Yes	Yes	Yes
Other Social Capital	No	No	No	No	No	Yes	Yes
Urban rural	No	No	No	No	No	No	Yes
N	7,403	7,403	7,403	7,403	7,403	7,403	7,403
r2_a	0.006	0.008	0.010	0.013	0.019	0.019	0.020
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: Processed Data (2024)
Note: The numbers in parentheses are the Standard Error (SE) adjusted in id
*** = 1% significance level, ** = 5% significance level, * = 10% significance level

To explore variations across different groups, Table 8 provides a subsample analysis, breaking down the effect by geographic and regional differences. The results indicate that women in non-Java regions experience a larger increase in social gatherings (0.20, $p < 1\%$) compared to women in Java (0.10, $p < 1\%$). Similarly, the effect is stronger in rural areas than in urban areas, suggesting that LPG conversion has a greater influence on social participation where traditional cooking methods were previously more time-consuming.

The subsample findings in Table 8 help explain and extend the overall trend observed in Table 7. While LPG conversion generally increases the number of social gatherings attended by women, the effect is not uniform across regions. Several factors could explain these variations. Higher reliance on traditional cooking fuels in rural and non-Java areas means that LPG adoption frees up more time, allowing for greater social engagement. Cultural and infrastructural differences may also play a role, as social participation patterns vary based on community structures and accessibility to social networks.

By integrating these insights, the analysis provides a more comprehensive and connected understanding of how LPG conversion affects women's social engagement, highlighting both the general impact and the variations across different demographic and geographic contexts. The estimation result on the social gatherings variable shows that the impact of LPG conversion can increase the number of social gatherings. The same thing was found by Aguiar & Hurst (2007) who found that women increased their leisure time due to a reduction in household production time. The impact of LPG conversion was more pronounced among women living in urban areas compared to those in rural areas. Additionally, women living outside Java Island experienced a greater impact of LPG conversion on the number of social gatherings than those living in Java. For all dependent variables, the results show that women in non-Java regions experienced a greater positive impact in terms of work hours and social gatherings compared to those in Java. In 2007, the population in Java was more likely to use non-LPG fuels than the population outside Java. However, by 2014, this trend had reversed, with the number of non-LPG users in Java declining compared to those outside Java.

Table 8. First Difference Model Estimation Results on Social Activity with Sub-samples

	(1) Socgath	(2) Socgath	(3) Socgath	(4) Socgath	899(5) Socgath
Cleanenergy(CE)	0.14***	0.16***	0.13***	0.10***	0.20***
	(0.022)	(0.034)	(0.032)	(0.034)	(0.031)
Individu	Yes	Yes	Yes	Yes	Yes
Head Household	Yes	Yes	Yes	Yes	Yes
Household	Yes	Yes	Yes	Yes	Yes
Wealth	Yes	Yes	Yes	Yes	Yes
Other Social Capital	Yes	Yes	Yes	Yes	Yes
Urban rural	Yes	No	No	Yes	Yes
N	7,403	3,811	3,592	4,026	3,377
r2_a	0.020	0.014	0.026	0.020	0.021
p	0.000	0.000	0.000	0.000	0.000

Source: Processed Data (2024)

Note: The numbers in parentheses are the Standard Error (SE) adjusted in id

*** = 1% significance level, ** = 5% significance level, * = 10% significance level

Model (1) show the results of all samples, Model (2) show the results for the sample in urban area, Model (3) show the results for the sample in rural area, Model (4) show the results for the sample in Java Island, and Model (5) show the results for the sample in rural Non-Java Island.

There is a possibility that in 2007 the population in Java mostly used kerosene, so when LPG conversion was present, the number of people who converted was greater. Besides, in 2007, there were more LPG users in Java than in non-Java. This indicates that there may be differences in the affordability of fuel access between Java and outside Java since it is more affordable in Java. The existence of this constraint on the affordability of access can result in longer time spent on obtaining fuel. Hence, with this LPG conversion, there will be greater time savings in areas outside Java.

3.2. DISCUSSION

The consistent positive impact of LPG conversion on both working hours and *arisan* participation aligns with the time allocation theory. This theory suggests that improvements in household production technology, such as switching to LPG, can increase efficiency. When household tasks become less time-consuming, women can reallocate their time towards more productive activities. In this case, the observed increase in working hours suggests that women are using their freed-up time to engage in market work. Furthermore, the increased *arisan* participation may indicate that women now have more discretionary time to participate in social and community activities, further demonstrating the impact of improved time allocation. Robustness checks, based on urban-rural classifications and regional differences between Java and non-Java areas, confirm the consistent positive impact of LPG conversion on both dependent variables. However, these analyses reveal variations in the strength of the effect across different subgroups.

LPG conversion has a larger effect on increasing both working hours and participation in social gatherings for individuals in rural areas compared to those in urban areas. This disparity likely arises from the greater reliance on non-LPG fuels in rural settings. Rural households frequently use firewood or biomass, often combined with kerosene, due to greater accessibility, while urban households tend to rely on single energy sources (Andadari et al., 2014). Because firewood and biomass require significantly more cooking time, the switch to LPG results in more substantial time savings for rural women, enabling them to dedicate more time to economic and social activities. Beyond the urban-rural divide, married women in non-Java regions see a greater positive impact from LPG conversion on both working hours and social gatherings compared to married women in Java.

Analysis across employment sectors further strengthens these findings, showing a more pronounced positive effect among informal workers. This result echoes Halim et al. (2017), who, in their study of preschool availability and women's labor force participation, concluded that such interventions primarily benefit women in the informal sector. They argue that the greater flexibility of informal work allows for easier adjustments to work schedules in response to time-saving changes in household production.

4. CONCLUSION

This study concludes that LPG conversion plays a crucial role in reshaping women's economic and social activities by reallocating time previously spent on household production, with observed increases in working hours and *arisan* participation demonstrating the potential of clean energy adoption to enhance women's labor market engagement and social connections. However, policymakers should recognize the heterogeneous impact of LPG conversion, as greater benefits are observed among rural, non-Java women, and informal workers, highlighting the importance of tailoring policies to specific regional and occupational contexts to maximize women's economic empowerment through household energy transitions.

Beyond fiscal and environmental considerations, other clean energy policies can increase women's work and socialization opportunities, potentially incentivizing other countries to implement such policies to achieve the 2030 SDGs. This research is limited by its focus on the impact of LPG conversion and does not explore the interdependence between work and leisure time. Future research should delve into the trade-offs women face between work and leisure after LPG conversion. It is crucial to determine whether the increased time availability predominantly results in increased work hours or if it also facilitates a shift towards more leisure pursuits. Qualitative research, including interviews and focus groups, can provide valuable insights into the factors influencing these choices.

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