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(Citation)
神戸大学経済学研究科 Discussion Paper,2120:1-28

(Issue Date)
2021-08

(Resource Type)
technical report

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/81013340

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August , 2021

Discussion Paper No.2120

GRADUATE SCHOOL OF ECONOMICS

KOBE UNIVERSITY

ROKKO, KOBE, JAPAN

Impact of LPG promotion program in Ghana:

The role of distance to refill

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Abstract

This study investigates the impact of a clean cooking intervention on primary fuel choice and on households' willingness to pay for an improved LPG distribution model in Ghana. Using data obtained via a survey of 904 households in two beneficiary districts, we found that the intervention led to higher LPG usage. The program increases the probability of households choosing LPG as a primary cooking fuel by 24% and the rate of use of LPG among households by 33%. Furthermore, an analysis of willingness to pay shows that delivery preference is not statistically different between beneficiary and control groups. The distance to refill the cylinder significantly affects LPG usage and willingness to pay. A policy that brings LPG refill closer to households and reduces the time and money cost of accessing a refill station is key to increasing the adoption of LPG as the primary cooking fuel.

Keywords: LPG; refill station; willingness to pay; distance; Ghana; RLPGPP

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1. Introduction

Cooking with solid fuels, such as firewood and charcoal, is still common in many developing countries. It is a major cause of household air pollution and leads to numerous health risks and mortality. An estimated death toll of more than 3 million annually can be linked to indoor air pollution (WHO, 2018). Research has shown that household air pollution from cooking with solid fuels has health implications, such as acute respiratory infections and cancer (Lim et al., 2013). The dangers associated with the use of such fuels have prompted governments and policymakers to enhance the uptake and adoption of improved and cleaner cooking practices.

Liquefied petroleum gas (LPG) is one of the cleaner cooking fuels strongly promoted in many countries. Interventions to promote LPG have taken various forms, ranging from providing equipment for free to households (Abdulai et al., 2018) to financial incentives such as subsidies on purchases (Calzada and Sanz, 2018). These interventions, including the provision of free LPG, have yielded mixed outcomes among different countries. A growing body of literature has examined the impact of programs to promote clean cooking (Carrion et al., 2018; Quinn et al., 2018; Troncoso and da Silva, 2017). While some studies suggest positive effects of such programs (Andadari, 2014; Calzada and Sanz, 2018; Kimemia and Annegarn, 2016), analyses in other areas show that these programs were ineffective (Abdulai et al., 2018; Adjei-Mantey and Takeuchi, 2019; Asante et al., 2018). Therefore, it is essential to evaluate the effects of clean cooking interventions to guide future programs.

In Ghana, the Rural LPG Promotion Program (RLPGPP) was rolled out in 2013 and continued for four years. The RLPGPP aimed to make LPG the primary cooking fuel for rural residents. The RLPGPP distributed free LPG cylinders, cookstoves, and accessories to rural households as they transitioned from firewood and charcoal to LPG, thus removing the initial cost barrier (Ministry of Energy, 2018). According to the Ghana Living Standards Survey (GLSS VII) data collected in 2017, LPG is the primary cooking fuel for 18.4% of households.[2] While the use of LPG among urban households is as high as 34.9%, only 6% of rural households use LPG as their primary cooking fuel. Ghana's 2012 Sustainable Energy for All Action Plan targeted a 50% household LPG access rate by 2020 (Energy Commission, 2012), and programs such as the RLPGPP were

[2] It slightly increased from the share of 16.9% in 2013 (GLSS VI). The proportions of Ghana households that use firewood and charcoal as primary cooking fuel stand 46.5% and 28.2%, respectively.

part of interventions to achieve the target. Documents provided by Ghana's Ministry of Energy, the implementing agency for the RLPGPP, show that 149,500 cylinders and 118,360 cookstoves with accessories were distributed in a third of districts nationwide from 2013 to 2017. RLPGPP has since been discontinued, but the effect of the program remains to be measured[3]. Concerning other LPG programs, the government of Ghana in 2017 proposed replacing the current LPG distribution system with a new one known as the LPG cylinder recirculation model. However, this program has not been implemented, and the existing distribution system has not been replaced.

This study contributes to the literature in three ways. First, we focus on the distance to refill stations as a key to promoting LPG usage. While several researchers evaluated the impact of clean cooking programs (Andadari, 2014; Calzada and Sanz, 2018; Kimemia and Annegarn, 2016), they did not thoroughly consider the impact of distance to obtain LPG on use. Because access to refill stations represents a considerable cost for rural households, it is crucial to examine their effect on fuel usage. Second, this study examines the treatment effect of a clean cooking intervention that reduces only the initial cost of use by providing free equipment. Although earlier studies have conducted similar impact evaluations in other countries, the interventions are mostly subsidies or contain a price support mechanism. For example, Calzada and Sanz (2018) explored Peru's program, which offers monthly vouchers to treated households to be exchanged for LPG. Kimemia and Annegarn (2016) examined South Africa's policy to control the maximum retail price of LPG. In both cases, the interventions included a subsidy or a price support mechanism, which continued over a long period, whereas the Ghanaian program provided one-time free LPG equipment. It is crucial to ascertain whether this marked difference relative to price leads to differences in the treatment effects. Initial setup costs are known to limit LPG usage, and hence the removal of these costs could represent a significant push towards a transition to clean cooking fuel. Furthermore, since affordability has been noted in the literature to be significantly related to LPG use (Karimu et al., 2016), a policy with continuous subsidies and price support systems is expected to have a good response from households. Previous evaluations of the RLPGPP in Ghana used a descriptive approach (Asante et al., 2018) or evaluated spillover effects at the district level (Adjei-Mantey and Takeuchi, 2019). This study differs from these studies in that it collects original survey data and

[3] Asante et al. (2018) found that the RLPGPP did not demonstrate an effective change in indoor air pollution while Kaali et al. (2019) documented that a similar cookstove intervention for pregnant women in Ghana reduced indoor air pollution.

uses micro-econometric analysis at the household level. Third, this study investigates the willingness to pay (WTP) for an improved LPG delivery system. By using the stated preference technique, studies such as Chindarkar et al. (2021), Zahno et al. (2020), and Jeuland et al. (2015) examined WTP to use LPG and improved cookstoves. Our study complements the above literature by focusing on the WTP for the delivery system as a practical and operational step of LPG use.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature, while Section 3 describes the data and the strategies to collect them. Section 4 explains the methodology adopted for analyzing the treatment effect, and the results are discussed in Section 5. Section 6 explores the WTP for LPG delivery services and their determinants, and Section 7 concludes the study with policy recommendations.

2. Literature Review

Several studies have investigated the impact of clean-cooking interventions. These intervention schemes take various forms across different countries. Calzada and Sanz (2018) evaluated Peru's program to substitute LPG for traditional stoves among low-income households. The beneficiaries received monthly discount vouchers under the program, which amounted to half the cost of an LPG cylinder. By applying matching techniques, the researchers observed that beneficiary households used LPG to cook 33%–38% more than non-beneficiaries. Additionally, they found no evidence that the use of LPG reduced respiratory problems in beneficiary households. Pollard et al. (2018) evaluated the same program in Peru using data from a different province. In addition to reporting a greater likelihood of LPG usage among beneficiaries, thus confirming Calzada and Sanz's (2018) findings, the study finds that kitchen concentrations of PM2.5, were lower for program beneficiaries, hence lower exposure to household air pollution among this group.

Kimemia and Annegarn (2016) evaluated the LPG intervention program in 2006 in Atteridgeville, South Africa. In 2010, the government followed up on the initial intervention by controlling the maximum retail price of LPG to boost uptake. The study reported that the program led to LPG substitution for combustion fuels among beneficiary households, making LPG the second most preferred cooking fuel after electricity, which was the most preferred possibly due to monthly subsidies. They further observed that 67% of respondents maintained regular use of LPG for cooking or heating seven years after the program was implemented.

The Indonesian government embarked on a fuel conversion program that involved removing subsidies on kerosene and reallocating them to LPG. Imelda (2020) evaluated the impact of the program on fuel choice and infant mortality. Overall, she found that the program increased the number of households that used LPG as primary fuel by 350%–900% while reducing total kerosene consumption by over 80% in four years. The study also found that the program reduced infant mortality by a conservative estimate of 25%, possibly through the channel of improved indoor air quality associated with LPG use. Andadari et al. (2014) also found that LPG consumption increased after the program, with a significant shift from kerosene usage across large sections of the population. This shift was due to the increased prices of kerosene because of subsidy removal. The study found that the program helped alleviate extreme energy poverty in Indonesia by substantially increasing LPG usage. Both evaluations of the Indonesian fuel conversion program confirmed the effectiveness of the program in promoting LPG use.

Few studies have been conducted on Ghana's RLPGPP. Asante et al. (2018) examined the program's effect in the Nkoranza North District of Ghana and observed that LPG usage was low among beneficiary households. After 18 months of program implementation, less than 10% of respondents still used LPG, and all respondents used firewood or charcoal as their primary fuel. Further analysis showed that the program did not yield significant changes in personal exposure to carbon monoxide. A study by Abdulai et al. (2018) in the same district found that financial constraints hampered the sustained use of LPG among beneficiaries by limiting their ability to afford the cost of fuel itself and that of commuting over long distances to refill their cylinders. They also found that factors promoting LPG use included quicker cooking time and reduced burden of firewood collection. Adjei-Mantey and Takeuchi (2019) examined the program's spillover effects at the district level using nationwide survey data. The study found no evidence of the program's significant impact in choosing LPG over fuelwood in beneficiary districts. The study, however, found that the RLPGG contributed to poverty alleviation in beneficiary districts. The potential channel was through the increased number of LPG refill stations established in beneficiary districts throughout the program's implementation. Apart from national level programs, Kaali et al. (2019) conducted a study in Kintampo municipality in Ghana to examine the effects of prenatal household air pollution on mitochondrial function and how clean cooking interventions could reverse the effect. The study found that children born in households that benefited from a randomized LPG intervention had higher mitochondrial DNA copy number (a biomarker used for many diseases) than children born in households that used efficiency biomass stove or traditional 3-stone fire stoves. This suggests that LPG intervention potentially reverses the effects of exposure to household air pollution.

In contrast to studies revealing the effectiveness of clean cooking interventions, studies in Ghana have not supported this narrative so far. The limitations of these studies can be summarized as follows. First, Asante et al. (2018) and Abdulai et al. (2018) did not compare beneficiaries to non-beneficiary households to measure program impact. Their studies either focused on the reach, effectiveness, adoption, implementation, and maintenance (REAIM) framework or used focus group discussions to reveal factors that enabled or inhibited LPG use and were both based solely on beneficiary households. This study contributes by comparing beneficiaries to non-beneficiaries under a quantitative framework to measure impact. Second, Adjei-Mantey and Takeuchi (2019) examined the program's spillover impacts at the district level, even though the program targeted selected households. Thus, there is a possibility that fuel choice changes at the household level were not large enough to impact the district level significantly. Therefore, an evaluation at the household level is necessary to ascertain the results in more detail. Finally, the other countries' programs used price support for consumers, such as subsidies and discount vouchers. Instead, Ghana's RLPGPP reduced the initial cost of introduction but did not include support for continuous usage, thereby not protecting consumers from high fuel costs. Because the downstream petroleum sector has been deregulated in Ghana, prices are not controlled and fluctuate due to market conditions. Examining the impact under this condition allows us to enrich the literature concerning program implementation.

Other clean cooking interventions involved the use of improved cookstoves (ICSs). ICSs require a lower amount of biomass fuel than traditional cookstoves and hence emit fewer pollutants. Empirical studies on ICS use have shown that interventions often led to increased adoption of cookstoves to improve clean cooking (Bensch and Peters, 2015; Bonan et al., 2021; Levine et al., 2018; Miller and Mobarak, 2014). Although there is a common feature with the current study, the evaluation of LPG intervention has a particular implication for understanding the policy that substantially reduces indoor air pollution.

Our study also relates to the strand of research that examined WTP for clean cooking. For example, Zahno et al. (2020) examined the role of health awareness on households' WTP for LPG and actual LPG consumption. The study found that WTP for LPG use increased when health information was provided. The distance to obtain LPG lowered the WTP, but this was not statistically significant. A related study by Chindarkar et al. (2021) examined the WTP to use LPG exclusively in rural India by employing a dichotomous choice approach. They also found that knowledge about the health benefits of LPG was a significant positive predictor of WTP.

In contrast to these studies, Beltramo et al. (2015) found that marketing information on the health-improving features of ICSs did not increase WTP for fuel-efficient cookstoves in Uganda. However, they also found that WTP was 40% higher when the payment due was over four weeks than within a week. The result highlighted the importance of liquidity or affordability barriers that households face when adopting ICSs. Similarly, Jeuland et al. (2015) used a discrete choice experiment to elicit WTP for improved cookstoves in India. They found that WTP was highest for the smoke-reducing attribute of the improved cookstoves, followed by the convenience of cookstoves and the reduction in fuel requirement. These findings suggest that households have a higher WTP to reduce smoke emissions, and LPG fits well into this cooking mode. While these studies are an important precedent of investigations on household preferences for clean cooking, they did not consider the WTP for a system that assures a constant supply of these fuels. Our study fills this gap by examining the WTP for LPG delivery to reduce access to further adoption barriers.

3. Data

3.1 Data Collection

We collected data by conducting face-to-face interviews in the Ga South[4] and Ada West districts of Ghana. The important factor in selecting these study areas was the availability of the list of beneficiary households of RLPGPP to identify treatment groups in the districts. Among the few

[4] Ga South is officially identified as a municipality. However, we refer to both Ga South and Ada West as districts throughout this study for simplicity.

districts for which Ghana's Ministry of Energy provided the list of households that benefitted from the program, the Ga South and Ada West districts' lists were complete, as they contained the contact information of each household. In both districts, 1,000 households benefitted from the RLPGPP, which was implemented in these districts in 2017.

According to estimates from the most recent population census conducted in 2010, Ada West has 11,642 households and a total population of 59,124, with 70.3% being rural residents, while Ga South has 100,701 households and a population of 411,377 with a 10% rural population (GSS, 2014a; GSS, 2014b). A larger proportion of Ada West settlements can be found in the coastal area, while Ga South has a relatively larger proportion of inland residents. The number of active refill stations operating in these districts at the time of the survey was seven for Ada West and 12 for Ga South.

We used electoral areas within the districts as enumeration areas (EAs) for the survey. In Ghana, electoral areas are geographical demarcations in each district for political administration and decentralized governance. The distribution of LPG equipment under the RLPGPP was done at the electoral area level, with lists of beneficiaries available for each district's electoral areas. Ada West has 15 electoral areas, and Ga South has 23 electoral areas. Considering the geographical balance, we sampled seven electoral areas in Ada West and 13 electoral areas from Ga South as EAs for the survey[5]. Following stratification of households on an electoral area basis, random sampling was employed to sample treated households using the beneficiary list information. We used a snowball sampling strategy to complement simple random sampling to select non-beneficiary respondents within the same EA to serve as a control group. The number of candidates for respondents in each EA was proportional to the number of households that benefited from the program in that EA. When candidates were unavailable due to relocation from the community, travel, non-cooperation, or unreachability, we replaced them with other households from the same EA.

The field survey was conducted using computer-assisted personal interviews (CAPI) from August 3rd to 31st, 2020. The exercise began with a training program for survey enumerators, after which a pilot survey was conducted to check whether the questionnaires were suitable and understandable

[5] A list of sampled EAs is provided in Appendix A.

to the respondents. The pilot survey also provided enumerators an opportunity to practice with the survey instrument ahead of the main exercise. After revisions of the instrument based on the pilot exercise's feedback, the main field survey was conducted by 14 enumerators. The total number of successful interviews was 904, of which 448 were conducted in Ada West and 456 in Ga South.

3.2 Data Description

Table 1 presents summary statistics of the data. The data showed that 45% of the sample benefitted from RLPGPP. As mentioned in the above section, the percentage is higher than the actual share of beneficiaries in each district, approximately 8.5% in Ada West and 1% in Ga South. The proportion of households that used LPG as their main fuel stood at 43%, while about 40% used LPG comparably more than other fuels in the seven days preceding the interview day. LPG usage rate is calculated as frequency of LPG usage in a day as a ratio of frequency of cooking in a day.[6] The mean LPG usage rate was 52%; on average, households used LPG once out of every two cooking times. Regarding occupation, 28% of the sample worked in the agricultural sector. On average, a round-trip to the nearest LPG refill station took 42 minutes (travel time only).

Table 1: Summary statistics of household characteristics and cooking fuel use variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Treatment	904	0.45	0.5	0	1
Distance to refill station (mins)	836	41.6	29.3	1	240
LPG is main fuel	904	0.43	0.5	0	1
LPG in past 7 days	904	0.44	0.5	0	1
LPG usage rate	866	0.52	0.45	0	1
Education (years)	904	7.4	4.5	0	16
Occupation (1 = agriculture)	904	0.3	0.45	0	1
Access to information	904	0.84	0.36	0	1
Access to financial services	904	0.66	0.48	0	1
Rural	904	0.77	0.42	0	1
Risk averse	904	0.77	0.42	0	1
District (1 = Ga South)	904	0.5	0.50	0	1
WTP (cedis) *	904	6.97	3.69	2	20
Household income (cedis)	904	1781.3	1697.7	0	22600

* Approximately, 1 Ghana cedi is equal to 0.17 US dollars.

[6] For example, if a household cooks thrice a day and uses LPG twice a day, this household's LPG usage rate becomes 0.67.

4. Empirical Methodology – LPG Usage

We employed a random utility framework to examine the factors that influenced household LPG usage. The framework assumes that the utility associated with a particular choice alternative is expressed as a function of observable and non-observable (stochastic) components. A household *i* chooses its main fuel from cooking fuel options *j* that includes LPG and other fuels (firewood and charcoal). The household chooses LPG as its main cooking fuel if the utility derived from using LPG, U_{LPG}, exceeds the utility from other fuels, U_{others} i.e.,

$$\mathrm{Pr}_i(LPG) = \mathrm{Pr}\left(U_{i,LPG} > U_{i,others}\right). \quad (1)$$

Based on the framework above, we specified a model that describes the probability of choosing LPG as the main fuel in the household, as follows:

$$\mathrm{Pr}_i(LPG) = \beta_0 + \beta_1 T_i + \beta_2 D_i + \beta_3 A_i + \beta_4 X_i + \varepsilon_i, \quad (2)$$

where *T* is a treatment indicator and took 1 if the household was the beneficiary of the RLPGPP. We expected the beneficiaries to have higher LPG usage because the intervention reduced the upfront costs and eased the burden of transitioning to LPG. *D* represents the round-trip distance to the nearest refill station. When the LPG in a cylinder is used up, households in Ghana must go to the station to refill them. Therefore, a longer distance to the station would reduce the probability of LPG usage. *A* indicates the occupation of the household head, whether an agricultural worker or not. We assume that it is easier for agricultural workers to obtain wood and biomass residuals as cooking fuel sources. They could also collect firewood on their usual commute to the farms and may have a lower time cost for firewood collection than non-agricultural workers. X is a vector of other factors that might affect household choices, such as income, education, and location. We used a probit model to estimate equation (2) and reported the marginal effects evaluated at the means. We further conducted heterogeneous analyses for different subgroups of the sample to explore which groups responded to the treatment. There was no strong correlation between any of the explanatory variables.

As a robustness check, we used two outcome indicators as alternative dependent variables: (1) LPG used more in the past seven days preceding the survey or otherwise, and (2) the LPG usage rate. Since households typically have multiple fuel types, the survey asked which fuel they used the most over the seven days preceding the survey. We limited the period to seven days for ease of recall. The LPG usage frequency rate also indicated whether LPG was often used in households. Both variables were used to confirm and check whether the regression results were robust to the choice of outcome indicator.

The above approach assumes that the Ministry of Energy randomly chose the beneficiaries of the RLPGPP. In the actual implementation of the program, there were no criteria for household selection in beneficiary districts. The field data showed that some beneficiaries owned LPG equipment before the program implementation and still benefitted from this program[7]. This affirmed the randomness in the beneficiary selection since all households stood the chance of benefiting from the program regardless of whether they owned LPG or not. Furthermore, given that households had nothing to lose if they opted out of the program, a randomly selected beneficiary household's chances to self-select themselves out of the program were meager. On this basis, the treatment was deemed exogenously determined; hence, the chosen approach is appropriate for estimating treatment effects. This notwithstanding, we considered potential biases in selecting households in some areas beyond the supervising authority's control. As an additional analysis, we used matching techniques to mitigate against potential bias from the possibility that some beneficiary households may not have been selected randomly. Based on the baseline covariates that were likely to affect the treatment selection, beneficiary households were matched with non-beneficiary households. Because treated and control households were matched on common characteristics, any differences in the outcome variables between treated and control households could be attributed to the treatment.

[7] Among the sample of treated households, 27.6% owned LPG before benefiting from the RLPGPP. We conducted a sub-sample analysis that excludes this group of treated households. The results are discussed in Section 5.

We used Mahalanobis distance matching (MDM) and propensity score matching (PSM) estimators. For every treated observation, the MDM calculates the distance between its covariates and those of control households and matches treated households with the control households with the shortest distance in covariates. Meanwhile, PSM allows us to estimate the probability of a household being treated (the so-called propensity score) based on its characteristics (Rosenbaum and Rubin, 1983). Each treated household is then matched with a control household that had similar propensity scores. In both cases, the matching was done on the following covariates: occupation, distance to the nearest refill station, access to financial services, access to information, education, location, and income.[8]

5. Results and Discussion

5.1 Treatment effect and determinants of LPG usage

Table 2: Main results: dependent variable = LPG is the main fuel (LPG = 1; otherwise, 0)

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Probit	Probit	Probit	MDM	PSM
Treatment	0.262***	0.218***	0.235***	0.223***	0.203***
	(0.032)	(0.034)	(0.036)	(0.040)	(0.044)
Distance to refill		-0.0037***	-0.0025***		
		(0.00065)	(0.0007)		
Other control variables	No	No	Yes	-	-
District effects	Yes	Yes	Yes	-	-
Observations	904	836	836	814	814

Note: Coefficients are marginal effects evaluated at the mean. Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Columns (1-3) of Table 2 show the probit estimation results on the factors that influenced the choice of LPG as the primary cooking fuel for the household. Columns (4-5) present the results from the matching estimators. The results shown in Table 2 indicate a positive and statistically

[8] Tables in Appendix B summarize the balancing properties of covariates for both matching estimators.

significant effect of the program. Treated households were more likely to choose LPG as their primary fuel by 23.5% compared to non-treated households (column 3). This finding suggests that the program contributed to increased LPG usage among the households that benefited from the program. The results from the MDM and PSM, shown in columns (4) and (5), confirm the positive impact of the program on LPG use, and the magnitude of the effect is consistent. Treated households increased LPG use as their main fuel by 20% to 22% compared to non-treated households. The coefficients' sizes were comparable to the estimates from the main results, as shown in (2) and (3).

The result is consistent with those of other studies on clean cooking interventions. The size of the treatment effect found in our study was smaller than that found in the Peruvian study by Calzada and Sanz (2018). This difference might be a result of the different features of the interventions. Beneficiaries in Peru receive a monthly voucher for LPG. However, this continuous LPG subsidy is not present in the RLPGPP in Ghana, and could lower the treatment effect. Our findings were inconsistent with those of Adjei-Mantey and Takeuchi (2019), who found no significant increase in LPG use. This result can be attributed to the differences in the study's focus. Adjei-Mantey and Takeuchi (2019) examined the district-level impact using data from official statistical surveys and found that the program did not yield significant spillover effects. In contrast, the current study examined the impact at the household level, which is the actual unit for treatment. The closer focus of the analysis in this study could account for the difference in results from the previous study.

The coefficient for the distance to the nearest LPG refill station was negative and statistically significant, suggesting that LPG usage decreases with distance. We found that for every minute increase in the travel time to access a refill station, the probability of choosing LPG as the main fuel reduced by 0.25%. A longer distance to a refill station represents higher monetary and time costs and reduces the choice of LPG as the primary cooking fuel. The result highlights the importance of providing an LPG distribution service that refills cylinders more conveniently with less time and travel costs. Dendup and Arimura (2019) noted that distance to the nearest market negatively affected the choice of LPG, while Dalaba et al. (2018) found no significant association between distance to a refill station and LPG ownership in northern Ghana.

To check the robustness of our choice of outcome indicator, we replaced LPG as the primary fuel with other dependent variables and compared the effect of treatment. Table 3 summarizes the results of the regressions with the alternative dependent variables. The marginal effects on the recent LPG usage (LPG in the past 7 days) and the LPG usage rate (ratio of LPG use to the total number of times of cooking in a day) are reported in columns (2) and (3), along with the main result (1), which is already indicated in column (3) of Table 2. Model (2) was estimated using probit and (3) by fractional probit regression.

The estimated coefficients for treatment in Table 3 are positive and statistically significant, suggesting a positive impact of the program on LPG choice. The chances of using LPG more than other fuels and usage rate of LPG were higher for treated households than for others by about 20% and 33%, respectively. These results are consistent with the main results from Table 2, which suggest a positive impact of the program on LPG use as the primary fuel. The significant effect of the distance to the nearest LPG refill station was also confirmed. An additional minute to a refill station reduces the probability of using LPG more than other fuels and LPG usage frequency by 0.3% and 0.4%, respectively.

Table 3: Other dependent variables

	(1)	(2)	(3)
	LPG is main fuel	LPG in past 7 days	LPG usage rate
VARIABLES	Probit	Probit	Fractional Probit
Treatment	0.235***	0.195***	0.333***
	(0.036)	(0.036)	(0.029)
Distance to refill	-0.0025***	-0.0027***	-0.0043***
	(0.0007)	(0.0007)	(0.00082)
Agricultural worker	-0.085*	0.017	-0.023
	(0.044)	(0.044)	(0.039)
Income	0.0039***	0.0038***	0.0039***
	(0.0012)	(0.0011)	(0.0012)
Education	0.030***	0.029***	0.020***
	(0.0044)	(0.0043)	(0.0035)
Risk averse	-0.066	-0.122***	-0.092**
	(0.046)	(0.045)	(0.037)
Rural	-0.28***	-0.279***	-0.29***
	(0.051)	(0.052)	(0.042)
District effects	Yes	Yes	Yes
Observations	836	836	798

Note: Coefficients are marginal effects evaluated at the mean. Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The estimated coefficients for the other control variables are also in line with expectations. Agricultural workers chose LPG as their primary cooking fuel at an 8.5% lower likelihood than non-agricultural workers in model (1). This result is consistent with the findings of Saksena et al. (2018). Farmers typically have easier access to wood and agricultural waste as a primary fuel, discouraging them from choosing LPG as their main fuel. Furthermore, it is a regular practice for farmers in Ghana to collect firewood on their usual commute to their farms. Hence, the time cost associated with gathering firewood might be lower for them. Jagger and Jumbe (2016) found that households that used crop residue as cooking fuel were more likely to adopt improved cookstoves (ICS). In that respect, their results differed from our findings. However, they examined the adoption of ICS while we examine the adoption of LPG. Transition to ICSs reduces the demand for biomass fuels but still requires it. Furthermore, the adoption of LPG implies that farmers cannot use such fuels. In line with previous studies (Choumert-Nkolo et al., 2019; Karimu et al., 2016; Muller and Yan, 2018), we found statistically significant and expected signs for other covariates, such as income, education, and rural location.

Table 4 presents results that exclude households that owned LPG before benefitting from the RLPGPP. The results can be regarded as a lower bound estimate because it measures the program's impact on treated households who became first-time owners of LPG equipment under the program without considering the program's impact on other beneficiary households. A positive and statistically significant impact of the program is observed among the sub-sample. Compared to the main results, the estimated treatment effects on LPG usage were lower. This is because households who own multiple LPG equipment will use LPG even more than households with single LPG equipment. While one cylinder is in use, another cylinder could be filled with LPG and be ready to substitute should the active cylinder run out of gas. Households with only one cylinder do not have this advantage. Therefore, if they run out of gas during cooking or when it is inconvenient to commute to refill their cylinders, they are likely to use firewood or charcoal as temporal substitutes.

Table 4: Exclusion of households that owned LPG before treatment

	(1)	(2)	(3)
VARIABLES	LPG is main fuel	LPG in past 7 days	LPG usage rate
	Probit	Probit	Fractional probit
Treatment	0.162***	0.118***	0.314***
	(0.039)	(0.039)	(0.032)
Distance to refill	-0.0021***	-0.0021***	-0.0041***
	(0.00071)	(0.00069)	(0.00086)
Agricultural worker	-0.063	0.021	-0.0088
	(0.045)	(0.045)	(0.042)
Income	0.0035***	0.0030**	0.0046***
	(0.0012)	(0.0012)	(0.0014)
Education	0.029***	0.028***	0.022***
	(0.0050)	(0.0044)	(0.0038)
Risk averse	-0.053	-0.097**	-0.12***
	(0.049)	(0.049)	(0.041)
Rural	-0.29***	-0.28***	-0.30***
	(0.057)	(0.057)	(0.048)
District effects	Yes	Yes	Yes
Observations	723	724	692

Note: Coefficients are marginal effects evaluated at the mean. Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5.2 Heterogeneous effects

This section investigates the heterogeneity in treatment effects, with the main purpose of deriving policy implications for similar interventions in developing countries. Based on the earlier findings, we considered three sub-groups: households that live closer or far from refill stations, agricultural or non-agricultural workers, and lower or higher income groups. We divided the distance by whether the round-trip travel exceeded 30 minutes. Income groups were divided by median household income in the sample.

Table 5: Heterogeneous effects; probability of choosing LPG as household's main cooking fuel

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Shorter distance	Longer distance	Agricultural worker	Non-agric. worker	Lower income	Higher income
Treatment	0.21***	0.25***	0.073	0.316***	0.308***	0.154***
	(0.055)	(0.047)	(0.066)	(0.042)	(0.047)	(0.050)
Distance to refill			-0.0017*	-0.0022**	-0.0024***	-0.0016
			(0.00098)	(0.00095)	(0.00093)	(0.00096)
Agricultural worker	-0.12*	-0.055			-0.089*	-0.077
	(0.067)	(0.055)			(0.054)	(0.064)
Income	0.0070***	0.0023*	0.0017	0.0050***		
	(0.0024)	(0.0013)	(0.0019)	(0.0016)		
Education	0.034***	0.024***	0.018**	0.036***	0.026***	0.029***
	(0.0069)	(0.0056)	(0.0083)	(0.0053)	(0.0060)	(0.0059)
Risk averse	-0.063	-0.088	-0.175*	-0.016	-0.018	-0.077
	(0.074)	(0.057)	(0.099)	(0.053)	(0.065)	(0.058)
Rural	-0.27***	-0.31***	0.011	-0.29***	-0.16*	-0.29***
	(0.066)	(0.087)	(0.152)	(0.058)	(0.091)	(0.065)
District effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	384	452	227	609	404	432

Note: Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5 summarizes the results. Models (1) and (2) show that the treatment had a slightly higher effect on households who lived farther from refill stations. The result suggests that the intervention's impact was more substantial for families living longer distances from a refill station. The importance of distance to access a refill station is crucial in households' decisions to use LPG and confirms the findings in earlier sections. In models (3) and (4), the treatment effect is not significant among agricultural workers but is significant among non-agricultural workers. Among non-agricultural workers, treated households were 32% more likely to use LPG as their main fuel than non-treated households. For agricultural workers, treated households were not likely to use LPG significantly more than non-treated households. For this subgroup, the treatment did not matter in terms of usage. As previously mentioned, the abundant supply of wood fuel and agricultural waste for agricultural workers provides a strong disincentive to use LPG. Saksena et al. (2018) also found that Vietnam's agricultural households had a positive and significant use of wood fuel. In models (5) and (6), the treatment effect was twice as potent in the lower-income group than in the higher-income group. These results agreed with those of Calzada and Sanz (2018) and Troncoso and da Silva (2017), who found similar conclusions in their study of cooking fuel interventions. This result suggests that a minimum level of income may be sufficient to induce LPG usage.

6. Willingness to pay for LPG delivery

This section explores the WTP for LPG delivery to assess households' preferences for an LPG distribution system. The current LPG distribution system in Ghana requires households to go to refill stations with their LPG cylinders when they run out. Refill stations may not necessarily be located close to a household's location, and the travel costs to a refill station increase households' difficulties in adopting LPG. We provided a hypothetical scenario in which LPG was delivered to the household upon a phone call in exchange for their empty cylinder. This system means that households do not have to worry about time costs or the inconvenience of carrying their cylinder to a refill station. They can also arrange for the cylinder to be delivered at a time convenient to them and hence do not have to alter their daily schedules. The exact text for the explanation in the survey questionnaire is as follows:

> Let's assume for a moment that there is a service which is akin to refilling your LPG cylinder at your home. This service brings you a cylinder which is similar to your cylinder in every way, filled with gas in exchange for your empty cylinder so that you do not have to make any trips to a refill station to refill your cylinder whenever your gas runs out. The service is prompt, reliable, and your gas will be delivered once a phone call is made without any hassle. The cost of the gas itself remains the same as what pertains at the refill stations. In addition, however, you may need to pay an extra amount as a fee for delivery of this service.

Following this explanation, we asked the maximum amount per delivery (aside from the gas price) the respondent was willing to pay as a choice from the list of fee options. The listed fees varied from 0 to more than ₵20 and increased by ₵2. This method was adopted to avoid biases associated with using a starting bid and a subsequent iterative bidding process to elicit WTP values while allowing for economically reasonable fees for the service based on the price of LPG and costs of commuting to refill stations. Box plots are used to analyze the data, and they show the distribution across different subgroups.

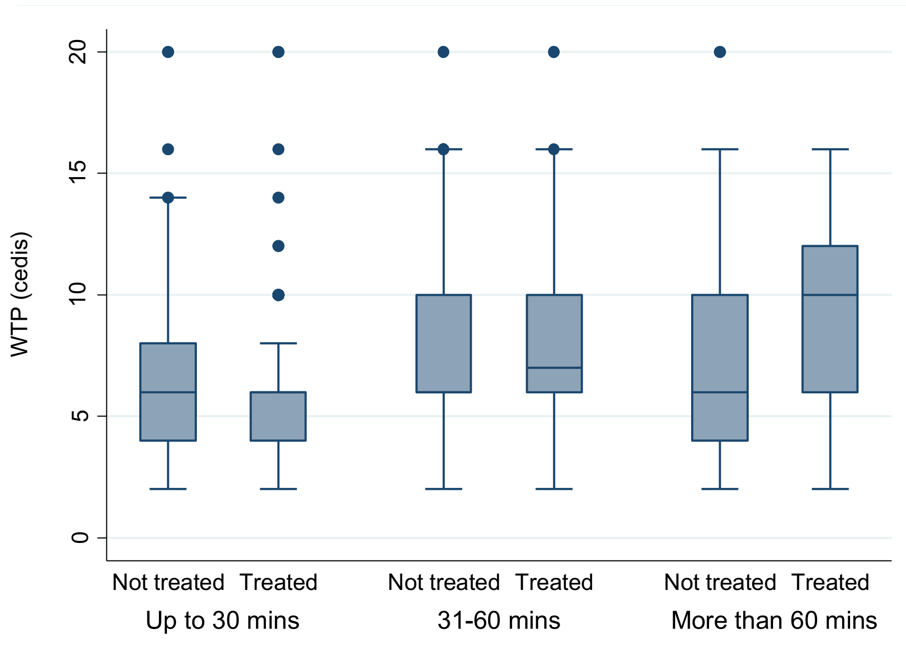

Figure 1: Distribution of willingness to pay

Figure 1 shows the distribution of WTP across treatment groups and the distance to refill stations. There appeared to be no significant differences in WTP between the treatment and control groups. The mean WTP for treated and control groups were ¢7.01 and ¢6.94, respectively, while the total mean was ¢6.97 ($1.20). This amount is about 22% of the average cost of refilling a 6 kg LPG cylinder at the time of the survey (¢31.14), which was the size of cylinders distributed under the RLPGPP. The distribution showed that households that live farthest from refill stations (more than 60 minutes round trip) had higher WTP than households that live closest to refill stations. The results aligned with expectations because households that live closer to refill stations are likely to incur lower money and time costs to travel to refill stations than households that lived farther.

In addition, we examined the factors that are likely to influence households' WTP by specifying the following model:

$$\text{WTP} = \alpha_0 + \alpha_1 T_i + \alpha_2 D_i + \alpha_3 A_i + \alpha_4 X_i + \varepsilon_i \quad (3)$$

where α_i are coefficients to be estimated, and T, D, A, and X are as previously explained in (2). Ordinary least squares (OLS) was used to estimate equation 3.

Table 6: Determinants of willingness to pay (WTP) for new LPG distribution system

Dependent variable: WTP amount (in Ghana cedis)

	(1)	(2)	(3)
VARIABLES	Full sample	Treated	Not treated
Treatment	0.101		
	(0.24)		
Distance to refill	0.040***	0.047***	0.030***
	(0.0044)	(0.0058)	(0.0067)
Agricultural worker	0.046	0.14	-0.15
	(0.29)	(0.40)	(0.42)
Income	0.0039	0.0036	0.0038
	(0.0070)	(0.0082)	(0.013)
Education	0.079***	0.13***	0.029
	(0.027)	(0.039)	(0.038)
Risk averse	0.283	0.20	0.36
	(0.29)	(0.40)	(0.43)
Rural	-0.32	-0.56	-0.0081
	(0.35)	(0.49)	(0.51)
Constant	5.223***	5.02***	5.57***
	(0.52)	(0.71)	(0.76)
District effect	Yes	Yes	Yes
Observations	837	408	429
R-squared	0.132	0.214	0.066

Note: Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6 presents the results from OLS estimation on the drivers of WTP. Regression results from Table 6 confirmed that the treatment had no significant effect on households' WTP for the proposed distribution system. However, distance to the refill station was positive and significantly associated with WTP. An increase in the travel time by 10 minutes increases WTP by ¢0.4 ($0.07) to access this service. Sub-sample analysis in columns (2) and (3) suggests that the effect of distance is stronger for treated households than for untreated households. Thus, the WTP of treated households was more sensitive than non-treated households. The results confirm the opportunity to implement the cylinder circulation model of LPG distribution, especially for communities located far from refill stations. Larsen et al. (2020) estimated that such a system has cost reduction potential of about 28% for rural households in Ghana and could increase rural LPG consumption by about 37%. Education was also found to increase WTP, similar to the findings of Chindarkar et al. (2021) and Zahno et al. (2020) that exposure to health awareness increases WTP for LPG in India.

7. Conclusions and Policy Implications

This study investigated the impact of the LPG promotion program in two districts of Ghana. We found that the program successfully increased the likelihood of choosing LPG as the household's primary cooking fuel, and the results were robust across different specifications. The distance to refill stations played a significant role in the decision to use LPG. Households that lived far from refill stations were less disposed to use LPG because of the obvious inconvenience and costs of commuting to refill stations. These households also had a positive and significant association with WTP for the proposed LPG delivery. This distribution model is similar to the LPG cylinder recirculation model proposed by the government of Ghana.

Based on our findings, we conclude that the distance to refill is crucial for successful clean cooking interventions. The construction of refill stations and providing stable services will increase the effectiveness of programs to promote LPG. In areas without refill stations nearby, the cylinder recirculation model that delivers an LPG cylinder to individual households will further assist the program's impact. The distribution system will make it easier and more convenient to use LPG, particularly for households far from refill stations. Furthermore, our findings indicate lower effectiveness of the program for particular subgroups of the population, such as agricultural workers. It may require a different form of support to encourage LPG usage among this sub-group of the population.

Acknowledgments

This research was supported by the Grant for Environmental Research Projects from the Sumitomo Foundation (Grant Number 193278) and Kobe University Center for Social Systems Innovation.

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Appendix A: Sampled EAs

Ada West	Ga South	
Afiadenyigba	Paanor	Kofi Kwei
Goi	Kokrobitey	Tuba
Wokumagbe	Weija	New Weija
Koluedor	Danchira	Gbemomo
Sege/Koni	Obom	Honi Ofadjator
Anyaman	Horbor	Jei Krodua
Addokope	Bortianor	

Appendix B: Covariate balance summary

The tables below show the differences between the treated and control households before and after matching for both estimators. After matching, the differences were significantly reduced for all covariates in both the MDM and PSM. For example, a difference before matching of 0.19 between treated and control concerning access to information reduces to an absolute difference of 0.008 after matching. These results show that matching makes the treated and control households more similar than the absence of matching.

Table B1: Balance before and after the matching

(A) Mahalanobis distance matching (MDM).

	Standardized differences		Variance ratio	
VARIABLES	Unmatched	Matched	Unmatched	Matched
Access to information	0.19	-0.0079	0.68	1.02
Access to financial services	0.21	-0.016	0.86	1.02
Distance to refill station	-0.16	0	1.01	1.04
Agricultural worker	0.10	0.016	1.11	1.02
Education	0.089	0.023	0.85	1.05
Income	0.14	0.060	2.39	1.19
Rural	-0.0076	0	1.01	1

(B) Propensity score matching (PSM)

	Standardized differences		Variance ratio	
VARIABLES	Unmatched	Matched	Unmatched	Matched
Access to information	0.19	0.0079	0.68	0.98
Access to financial services	0.21	-0.055	0.86	1.060
Distance to refill station	-0.16	0.036	1.01	1.12
Agricultural worker	0.10	0.082	1.11	1.09
Education	0.089	0.024	0.85	0.89
Income	0.14	0.077	2.39	1.64
Rural	-0.0076	-0.040	1.01	1.05