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Catching up with peers: Investigating the long-run dynamics of an LPG promotion program in Ghana

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ABSTRACT

Household energy transitions to cleaner fuels remain a major challenge in developing countries, which have low adoption rates of modern energy sources. This study investigated the long-run effects of a clean energy transition policy, focusing on a liquefied petroleum gas (LPG) promotion program in Ghana. We conducted household surveys in Ghana during 2020 and 2023, corresponding to 3 and 6 years after the end of the program, and collected longitudinal data from 1632 households (905 in 2020 and 727 in 2023). Our analyses show a short-term boost in LPG adoption among intervention households that received LPG cylinders from the program. Using a household fixed-effects approach, we find that, 6 years later, non-intervention households in the program community with children aged under 5 years increased their LPG adoption by 34.5 % relative to households without children, despite not having received direct support from the program. Further analysis reveals that the extension of LPG usage was limited to households with at least one peer in their social network who was an LPG user as well as the perception of LPG as a safe energy source for health. The findings suggest that energy transition can be promoted cost-effectively by incorporating the roles of social networks and information sharing, provided that fundamental infrastructure for LPG provision has been established.

1. Introduction

Indoor air pollution poses a major public health concern, particularly in developing countries, leading to an estimated 3.2 million related deaths annually [1]. The primary source of pollution is the use of solid fuels in the household, such as wood, charcoal, and crop residue. Households continue to use traditional solid fuels under various constraints and conditions, exposing themselves to pollutants, such as fine particulate matter, and significant health risks [2]. Although various policies promote the transition to cleaner energy by households, including providing cylinders and stoves, subsidizing fuel costs, and installing refueling stations for liquefied petroleum gas (LPG), these forms of support generally reach only a limited number of households [3]. Currently, more than 2 billion people lack access to clean fuels and technologies [4]. Notwithstanding resource and financial constraints, promoting the use of clean fuels among low-income households is essential for achieving the energy goals outlined in the Sustainable Development Goals.

Existing literature has highlighted that policy intervention can promote the transition to cleaner household energy [5–7]. For example, an intervention in one study offered cookstoves to randomly selected recipients, resulting in a higher adoption rate of the new cookstoves for recipients compared to non-recipients in the short run [8]. Although such interventions have increased the number of LPG users by reducing adoption costs, the influence of economic factors remains ambiguous. Households with higher income did not consistently have a higher probability of using LPG. This finding suggests that psychological burdens and access difficulties hinder households' shift to new energy sources [9].

Among the psychological factors that may affect clean energy

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adoption, recent studies have investigated the significance of peer effects, that is, the influence of social group interactions on individual behavior [10]. The presence of clean energy adopters in a community may reduce the psychological burden of adoption, leading to a higher probability of clean energy adoption in the community [11,12]. These findings provide new insights for a comprehensive evaluation of energy transition policies. An energy transition policy supports specific targeted households in the community, boosting their clean energy adoption rate; however, non-targeted households typically receive no support or incentives offered by the intervention. In the context of peer effects, non-targeted households may also increase the probability of adopting clean energy because the overall number of clean energy users (peers) would have increased owing to a policy intervention in the community. Although the comprehensive effects of the transition policy on new energy adoption need to include spillover effects on non-targeted households, these effects are yet to be fully understood. This lack of understanding may be attributed to the difficulty in examining the spillover effects on non-targeted households, which require long-term observations of non-targeted households spanning several years after policy implementation.

This study examines the consequences of a clean energy transition policy, focusing on households living in the targeted community yet receiving no support from the program. Specifically, we investigate the effects of the LPG-promoting program on the probability of clean energy adoption in both targeted and non-targeted households using data derived from two rounds of household surveys conducted 3 and 6 years after Ghana's LPG program ended. The comprehensive effect of the energy transition policy on household decisions to adopt clean energy in Ghana is particularly worthy of investigation. Ghana has substantial solid fuel dependence for residential energy compared with the other countries in West Africa, leading to significant social and health concerns regarding indoor air pollution [13]. In Ghana, indoor air pollution is estimated to cause approximately 11,700 premature deaths and 426,000 disability-adjusted life-years annually [14]. The government of Ghana has prioritized addressing the social and health concerns associated with indoor air pollution. Between 2013 and 2017, the government implemented a preliminary program to provide LPG cylinders and cookstoves to rural households. In 2018, the government approved a program for distributing LPG cylinders and cookstoves to 2 million households, aiming to promote energy transition by 2030 as part of a national action plan [15]. This context enables us to investigate the long-term effects on households in Ghana.[1]

There is substantial literature on the long-term impacts of interventions in various fields and across varied subjects. In a meta-analysis of reading intervention studies, Suggate [16] showed that interventions on comprehension and phonemic awareness had impacts that persisted in the long term while phonics and fluency interventions were less effective in the long term. Watts et al. [17] showed that an intervention offering school teachers targeted coaching on student behavioral management and teacher stress reduction had long-term impacts on student grades but none on behavioral problems. In housing, a study on the impacts of an intervention that offered permanent subsidies to beneficiaries showed long-term residential stability and reduced homelessness among recipients of the subsidy as well as other benefits, such as improved food security, as a long-term impact [18]. These studies demonstrate the relevance of evaluating interventions beyond the short term and the potential lessons to be learned from long-term effect studies.

The principal findings of this study are as follows. First, the energy transition program in Ghana increased the number of LPG users in the community in the short term. Treated households that received LPG cylinders and cookstoves were 41.9 % more likely to use LPG than non-treated households that did not receive these items. However, our estimates also indicate that the difference in the LPG adoption rate between treated and non-treated households diminished 6 years after the program. This can be attributed to the increased number of LPG users among non-treated households. The LPG usage rate among non-treated households 6 years later increased to the same level as that among treated households, although the non-treated households did not receive any support or incentives from the program.

Second, having children was a key factor in increasing the choice of LPG among non-treated households. Households with children aged under 5 years were 34.5 % more likely to use LPG than those without children. Third, the impact of having children on LPG adoption was limited to households with at least one LPG user in their social network and the perception of LPG as a safe energy source for their health. The results suggest the importance of peer effects and providing information to promote the energy transition among non-treated households.

A potential threat to identification arises if a household's decisions to have a child and use LPG are systematically related to confounding factors. In the analyses, we control for possible endogeneity in LPG adoption considered in previous studies, such as household income, household head characteristics, and distance to the nearest refill station. In addition, we control for household and survey-year fixed effects. Because these fixed effects capture unobserved household characteristics and time-dependency factors, our estimates can be interpreted as within-household variation. However, selection issues owing to unobservable variables may still arise, with potential bias from the endogenous sorting of households' decision to have a child into LPG adoption. We address this issue by applying Oster's [19] bias-adjusted estimates. The results show that the bias-adjusted coefficients are similar to those of the main analyses, suggesting that selection bias is negligible.

This study contributes to three strands of the literature. First, it extends the literature on household responses to interventions in energy transition policies in developing countries. Many studies have highlighted that households are more likely to adopt clean energy in response to interventions when a stable energy supply is ensured [7,20–24]. Typically, these studies have examined the short-term effects of interventions by comparing clean energy adoption rates between households that received policy support and those that did not. Our results align with these studies in the short term and further indicate the possibility of an increase in adoption among households that have received no support or incentives in the longer term. Indeed, this study is among the first to examine the long-term effects of an LPG intervention in Ghana. These findings suggest that previous studies have underestimated the impact of policies or programs promoting clean energy adoption in developing countries.

Second, our study contributes to the literature on the determinants of household choice to adopt clean energy in developing countries. Many studies have investigated the various factors involved in the energy transition (see the review in [25]; [26]). For example, a household's decision to adopt clan energy is linked to its economic status [27,28], educational background [29,30], electricity connection [31], and access to refill stations [21,32]. However, many of these studies rely on cross-sectional data, which may lead to a concern of potential confounders, with limited capacity to address endogeneity in adoption and associated factors [33]. Our study addresses this issue by using panel data at the household level and applying a fixed-effects approach. Additionally, the bias-adjusted estimators used in this study allow us to check the robustness of our findings against selection issues arising from omitted observations.

Third, our study presents evidence that peer influence can help clean energy adoption within the context of energy transition policies in developing countries. Peer presence affects household energy choices through economic status, social norms, and information-sharing effects [12,34]. Recent studies have shown that the peer effect or presence of clean energy adopters in village networks can promote households' energy transition [11,35–37]. Our results indicate that the peer effect is a precondition for adoption rather than independently promoting clean

[1] The details of the distribution program and its progress are presented in Section 2.

energy adoption. Households are more likely to adopt LPG when they have children; this effect is observed only in the presence of the peer effect, specifically, when an LPG adopter exists within their social network. These findings provide a deeper understanding of the peer effect and suggest a detailed mechanism for its interaction with household characteristics.

The remainder of this paper is structured as follows. The rest of Section 1 provides background on household energy use in Ghana and outlines the cylinder and cookstove dissemination program conducted from 2013 to 2017. Section 2 details the study's data and empirical strategies. Section 3 presents the estimation results. Section 4 concludes.

1.1. Cooking fuels in Ghana

The most common cooking fuels used in Ghana are firewood, charcoal, and LPG. Traditional fuels, such as firewood and charcoal, dominate primary cooking fuels, with a smaller share of households adopting cleaner alternatives, mainly LPG. As of 2021, more than 50 % of households in all but one of Ghana's 16 regions used firewood or charcoal as their main cooking fuel, with seven regions having at least 75 % of households that resort to these traditional fuels as their primary cooking fuel [38]. This demonstrates the huge reliance on traditional and heavily polluting cooking fuels. The use of LPG as a primary cooking fuel is generally low, and its penetration is higher in urban areas than in rural areas. This could be attributed to better infrastructure supporting the distribution of LPG in urban areas than in rural areas. Furthermore, higher incomes in urban areas suggest a better ability to pay for modern fuel compared with rural areas. Statistics from the population and housing census conducted in 2021 indicate that LPG is used by 36.9 % of households across the country. In urban areas, one in two households (51.3 %) use LPG as the primary cooking fuel. By contrast, the LPG penetration rate in rural areas is low (14.8 %) [38]. However, fuel stacking is not uncommon in Ghana, and households typically use more than one fuel type, even if they classify a particular fuel type as their primary cooking fuel. Other fuels adopted by households are used to complement their primary fuel, such as when they prepare specific meals for which their secondary fuel type is suitable or when their primary fuel is scarce.

The dominance of traditional cooking fuel in Ghana contributes significantly to air pollution, particularly by emitting fine particulate matter ($PM_{2.5}$), including black carbon. This is primarily because of incomplete combustion or the use of inefficient cooking stoves for wood or charcoal. Residential cooking contributed nearly 78 % of black carbon emissions in Ghana in 2017, with three-fourths of these emissions emanating from rural areas [39]. Household cooking was the largest contributor to $PM_{2.5}$ also, accounting for approximately 62 % of the total primary emissions in 2017, leading to high levels of household (indoor) air pollution [39].[2] Household cooking is estimated to remain the primary source of $PM_{2.5}$ in Ghana over the next 2 decades [39]. Additionally, residential cooking and lighting (mainly from standby generator use) were responsible for approximately 22 % of emissions of carbon dioxide in 2017 [39], although fractions of non-renewable biomass of these sources should also be considered when evaluating their climate impacts [40]. To address effects from traditional cooking fuel emissions and adverse health implications, in line with Ghana's climate change policy to reduce emissions, the government embarked on a clean cooking agenda. A key strategy was promoting LPG for cooking, particularly in rural areas that are more deprived of clean cooking fuels. A flagship program implemented in this policy is the Rural Liquefied Petroleum Gas Promotion Program (RLPGPP).

[2] In this study, household air pollution and indoor air pollution are used interchangeably.

1.2. The rural Liquefied Petroleum Gas promotion program

The switch from traditional fuels to LPG normally comes with initial fixed costs, such as the costs of the LPG canister, a compatible cookstove, a portable gas regulator, or a tube that carries the gas from the cylinder to the cookstove. These costs may prove prohibitive for potential LPG users, especially in rural areas where incomes are generally low. To address these high switching costs, the RLPGPP was implemented by the government of Ghana through its Ministry of Energy. The RLPGPP is the government's energy transition intervention aimed at promoting the uptake of LPG in rural areas. The RLPGPP is expected serve as a tool for achieving widespread adoption of LPG as a primary cooking fuel in rural areas of Ghana. The program began in December 2013 and continued until 2017. The program operated as follows. An LPG canister (cylinder) filled with LPG, a cookstove, and complementary accessories were provided to beneficiary households in selected districts free of charge [41]. This was expected to address initial switching costs and allow LPG users the opportunity to switch to LPG without facing cost barriers. However, subsequent refills of the cylinder were borne by households.[3] Having taken care of the initial costs through the RLPGPP, the uptake of LPG was expected to increase, especially in beneficiary communities [42]. By the end of 2017, the government had distributed 149,500 units of 6-kg cylinders and 118,360 single-burner cookstoves with accessories, including gas regulators and gas tubes, across 50 municipalities and districts in the country [42].

2. Empirical design

2.1. Data collection

We conducted face-to-face interviews and collected data from Ga-South and Ada-West districts.[4] Fig. 1 shows the study sites. In these districts, the government of Ghana provided households with LPG cylinders, cookstoves, and accessories between 2013 and 2017 to promote household energy transitions under the RLPGPP. The initial survey was conducted in 2020 and a follow-up survey was conducted in 2023. The survey instrument and data collection process were reviewed and subsequently approved by an institutional ethical review board. The data collection process followed standard ethical procedures where informed consent was sought from each respondent prior to the administration of the questionnaire while confidentiality of data was assured. The data collected and the procedure used brought no direct nor indirect physical or mental harm to respondents. Trained enumerators were enlisted to provide support in administering the field survey with the research team on hand to ensure accuracy and integrity of the data collected. The surveys were designed to obtain information on the types of household cooking fuel, number of children, perspectives on LPG and solid fuel, distance to refill stations, and demographic characteristics of households.[5]

In the first survey, we used the list of treated households in the RLPGPP obtained from the local authority, that is, the district assembly, to identify the households that received cylinders and cookstoves. Stratified sampling was first employed to stratify households into the various enumeration areas (EAs) for the survey. The EAs were based on the electoral areas within each district which was also the level at which the treatment was carried out. Following the stratification, simple random sampling was used to select treated households within each EA from the list of beneficiaries. To select non-beneficiary households to be

[3] In Ghana, LPG users typically have to take their empty canisters to a refill station to purchase LPG when they run out of fuel.

[4] Districts are the second sub-administrative level in Ghana. Ga South is officially termed a municipality (a variant term for "district" if the area has a larger population than a district normally has). However, in this study, we refer to both districts and municipalities as districts for ease of reference.

[5] The questionnaire is provided in Appendix B.

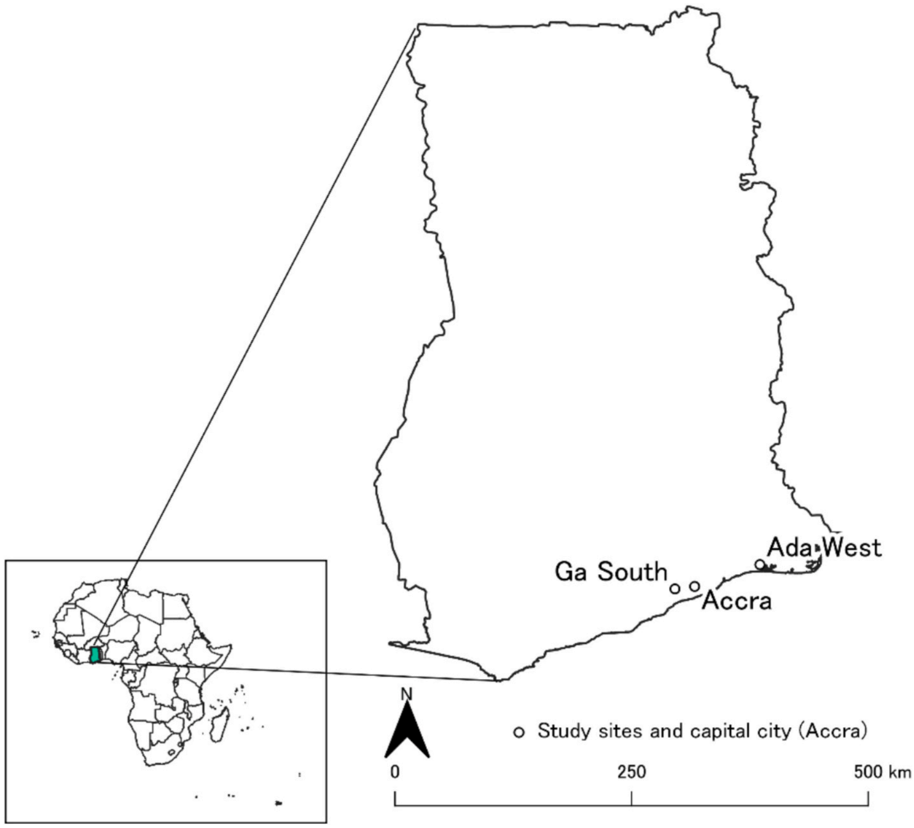

Fig. 1. Map of study sites.

in the control group, simple random sampling and snowball sampling were employed within each EA. A total of 905 responses were collected; 45.3 % of the households received cylinders and cookstoves from the local government under the RLPGPP and 54.7 % did not. In the follow-up survey conducted in August 2023, 727 respondents from the first round of the survey were revisited and interviewed; 48.1 % of households were cylinder and cookstove receivers under the program, and 51.9 % did not receive them.[6] There was no significant difference in attrition between recipients and non-recipients.

2.2. Data description

Table 1 reports the summary statistics of the main empirical variables for the surveys conducted in 2020 and 2023. We defined households reporting that they used LPG as the main cooking fuel for the last 7 days as LPG users.[7] The rate of LPG use increased from 39.8 % in 2020 to 48.4 % in 2023. Between 2020 and 2023, other programs and interventions related to LPG promotion were not implemented. Therefore, the rate of LPG use was raised mainly by households' decision to avoid using solid fuel and rather use LPG. The economy and infrastructure improved substantially during this period. For example, the average monthly income in the sample increased from 1781 to 3100 Ghana cedis, and the rate of electrified households in the sample increased from 91 % to 100 %. In addition, distance to refill stations, measured by the time it takes to make a round-trip travel to the nearest LPG refill station, decreased slightly from 56.5 min in 2020 to 45.8 min in 2023. This may be because of the establishment of new refill stations in the Ada West district. We controlled for these possible endogenous variables in our estimations.

2.3. Empirical specification

This study explored household decisions to use LPG as a cooking fuel, focusing on within-household variation. We estimated the following equation, which includes household and survey-year fixed effects:

$$Y_{ht} = \alpha + \beta_1 Child_{ht} + \beta_2 Income_{ht} + \beta_3 Distance_{ht}$$

$$+ \gamma Treatment_h + X'_{ht}\delta + \lambda_h + \mu_t + \varepsilon_{ht}, \quad (1)$$

where h and t denote the household and survey year, respectively.

Y_{ht} represents a dummy variable that takes the value of one if the household uses LPG as the main cooking fuel and zero otherwise. $Child_{ht}$, $Income_{ht}$, and $Distance_{ht}$ denote within-household variables. $Child_{ht}$ is a dummy variable that takes the value of one if the household has a child under 5 years and zero otherwise. $Income_{ht}$ is the natural logarithm of the household monthly income. $Distance_{ht}$ is the natural logarithm of reported round-trip time to the nearest refill station. $Treatment_h$ is a dummy variable that takes the value of one if the household received LPG cylinders in the RLPGPP and zero otherwise. Based on the program implementation structure, *Treatment* is deemed sufficiently random, as all households within a selected district could benefit from the program irrespective of any unique feature of the household. We do not expect a household randomly selected to benefit under the program, to self-select out of the program, as there was nothing to lose by accepting the free LPG equipment. Therefore, any likelihood of such self-selection out of the program would be minimal. Indeed, Adjei-Mantey et al. [21] used sub-sample analyses to show that the treatment under the RLPGPP was sufficiently random. Note that $Treatment_h$ is a time-invariant variable, because it represents the household experience in the RLPGPP. Thus, the effects of the RLPGPP cannot be observed in the fixed-effect

[6] The attrition rate is 19.7 %.

[7] Some of the variables indicating household characteristics are shown as a dummy variable taking the value of one or zero. For example, the variable takes the value of one if the household used LPG as the main cooking fuel for the past 7 days and zero otherwise.

Table 1
Summary statistics.

	Observed in 2020 (N = 905)				Observed in 2023 (N = 727)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
LPG is the main fuel	0.398	0.490	0	1	0.484	0.500	0	1
Treatment in 2017 (RLPGPP)	0.453	0.498	0	1	0.481	0.500	0	1
Having children aged <5 years	0.779	0.415	0	1	0.437	0.496	0	1
Natural logarithm of household monthly income (Ghanaian cedis)	7.176	0.938	0	10.026	7.761	0.749	4.615	9.976
Household electrified	0.910	0.286	0	1	1	0	1	1
Male head	0.535	0.499	0	1	1	0	1	1
Head aged <25 years	0.027	0.161	0	1	0.007	0.083	0	1
Head aged 26–35 years	0.176	0.381	0	1	0.132	0.339	0	1
Head aged 36–45 years	0.326	0.469	0	1	0.334	0.472	0	1
Head aged 46–55 years	0.291	0.454	0	1	0.333	0.472	0	1
Head aged >55 years	0.181	0.385	0	1	0.194	0.396	0	1
Head not educated	0.209	0.407	0	1	0.187	0.390	0	1
Head primary-school educated	0.185	0.388	0	1	0.160	0.366	0	1
Head middle-school educated	0.409	0.492	0	1	0.459	0.499	0	1
Head secondary-school educated	0.136	0.343	0	1	0.146	0.353	0	1
Head tertiary-educated	0.062	0.241	0	1	0.048	0.214	0	1
Head not employed	0.082	0.274	0	1	0.070	0.256	0	1
Head employed	0.197	0.398	0	1	0.089	0.286	0	1
Head self-employed	0.722	0.449	0	1	0.840	0.366	0	1
N of household members	6.881	4.808	1	80	5.366	3.465	1	35
N of LPG users around the household	4.114	6.758	0	10	4.528	3.372	0	10
(at least one) LPG users exist around the household	0.880	0.325	0	1	0.880	0.325	0	1
Distance to refill station (minutes)	56.483	59.462	1	240	45.810	37.310	0	240
Rural	0.775	0.418	0	1	0.739	0.440	0	1

Notes: This table reports the mean, standard deviation (S.D.), and minimum (Min.), and Maximum (Max.) values in the samples collected in 2020 and 2023. The missing values for the variables were replaced by the mean values of each variable and year, and dummy indicators for the missing values were included in the estimations.

specification owing to perfect collinearity with the household fixed effect. We also include other household and district characteristics as potential predictors of household fuel choice. X'_{ht} is a vector of the observed household and district covariates, including age, sex, education, employment status of the household head, number of household members, electrification of the household, and whether the community is classified as a rural area. In addition, the model includes household fixed effect λ_h and survey-year fixed effect μ_t. Standard errors are clustered at the household level in the fixed-effect estimations. The household fixed effect captures the unobserved household characteristics, including cooking procedures and potential factors affecting fuel choice. The survey-year fixed effect captures the unobserved variations that affect fuel choice equally across households. For instance, the survey-year fixed effects consider rising demand for cleaner fuels over time in Ghana. ε_{ht} is an error term.

The estimation model includes observed variables that may affect fuel choice. Additionally, the fixed effect further controls for possible endogeneity in fuel choice. However, the analyses in this study relied on observed data and suffered from possible residual endogeneity or selection bias. To ensure the robustness of our estimations, we estimated the bias-adjusted coefficients provided by Oster [19] in Subsection 4.4.

3. Results and discussion

3.1. Effects of the LPG promotion program

We begin by exploring the impact of the LPG cylinder distribution under the RLPGPP conducted between 2013 and 2017 on LPG usage within the targeted communities. We estimate the effect using cross-sectional data for 2020 and 2023 because the treatment indicator ($Treatment_h$) is time-invariant. Table 2 reports the estimated effects of the RLPGPP on the probability of using LPG as the primary cooking fuel. Columns (1)–(3) present the estimated coefficients using the samples surveyed in 2020, while columns (4)–(6) list the effects using the same samples 6 years later (2023). These columns report the estimates without additional controls in columns (1) and (4), with controls for household covariates in columns (2) and (5) and district-level covariates in columns (3) and (6).

The coefficients of *Treatment* are positive and statistically significant for the 2020 samples, while those for the 2023 samples are small and statistically insignificant. These results remain robust even after the inclusion of additional controls. In column (3) of Table 2, the coefficient of the intervention, controlling for household and district covariates, is 0.167. This indicates that in 2020, the treated households that received cylinders had a 41.9 % higher probability of using LPG than the non-treated households that did not receive cylinders.[8] However, the estimates for the 2023 samples in columns (4)–(6) suggest no difference in the probability of LPG use between treated and non-treated households.

This reduction in the treatment effect is attributed to an increase in the probability of using LPG among non-treated households. Fig. 2 shows that the rate of LPG use of non-treated households increased from 33 % in 2020 to 49 % in 2023, whereas that of treated households decreased slightly between 2020 and 2023. There is no significant difference in the rate of LPG use between treated and non-treated households in 2023.

Our findings indicating that cylinder provision increases short-term LPG use are consistent with those of previous studies (e.g., [8,21]). Additionally, our estimations indicate that the subsequent advantage of the LPG usage rate among treated households dissipated 6 years later. This shift can be attributed to the increase in LPG use by non-treated households relative to treated households.

3.2. Effects of within-household variation of LPG use

We now examine the effect of within-household variation on LPG use as cooking fuel, based on Eq. (1). Table 3 presents the estimation results for the key household variables. These estimates represent the effects of within-household variation. Columns (1)–(2) provide the estimates for all samples, while columns (3)–(4) and (5)–(6) show households that received and did not receive any equipment in the RLPGPP, respectively. These columns report estimates without additional controls and with

[8] The sample mean of LPG users is 0.40.

Table 2
The effects of the cylinder dissemination program on LPG usage in 2020 and 2023.

	2020			2023		
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment (RLPGPP) in 2017	0.224***	0.195***	0.167***	−0.057	−0.050	−0.049
	(0.032)	(0.031)	(0.031)	(0.037)	(0.037)	(0.037)
Observations	905	905	905	727	727	727
Adj. R-squared	0.059	0.203	0.240	0.007	0.044	0.053
Household Controls		Yes	Yes		Yes	Yes
District Controls			Yes			Yes

Notes: The dependent variable is a dummy indicator that takes the value of one if a household uses LPG as the main cooking fuel. Standard errors are clustered at the household level and reported in parentheses. *** denotes statistical significance at the 1 % level. Household Controls included income, age, sex, education, and employment status of the household head as well as the number of household members. District Controls include distance to the refill station and whether the community is classified as rural.

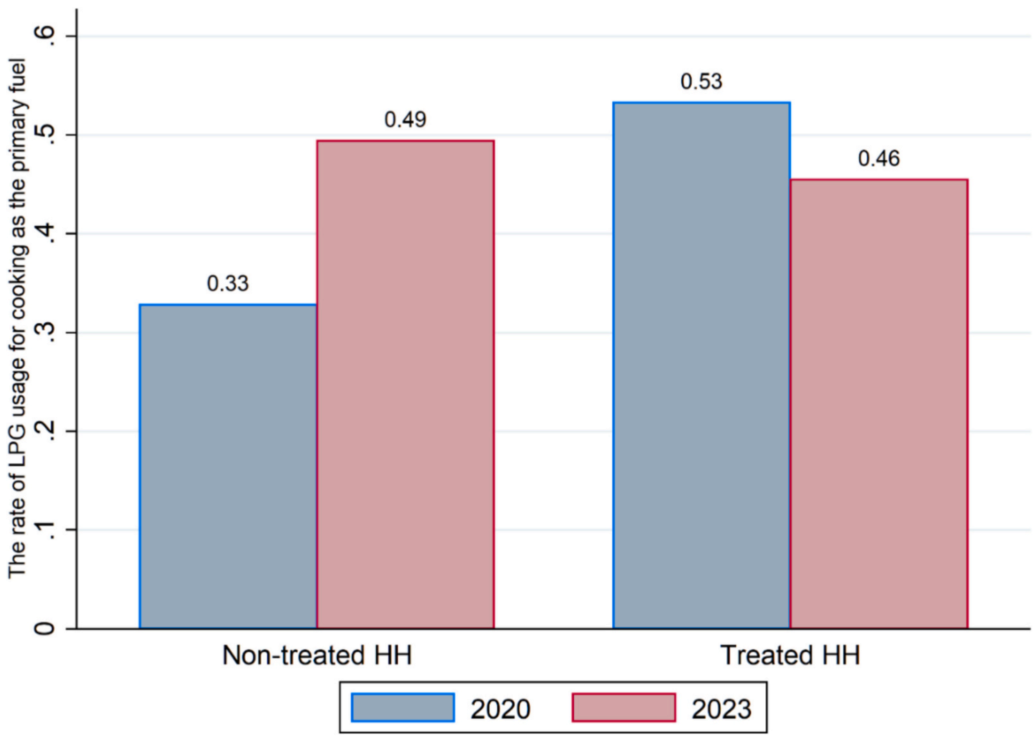

Fig. 2. Rate of LPG usage as the primary cooking fuel.

Table 3
The effects of within-household variations on LPG usage.

	All		Treated households		Non-treated households	
	(1)	(2)	(3)	(4)	(5)	(6)
Having children aged <5 years	0.027	0.025	−0.059	−0.075	0.125**	0.145**
	(0.044)	(0.044)	(0.062)	(0.061)	(0.060)	(0.061)
ln(income)	0.023	0.025	−0.009	−0.003	0.028	0.039
	(0.024)	(0.026)	(0.037)	(0.041)	(0.031)	(0.035)
Distance to station	−0.001***	−0.002***	−0.001	−0.001	−0.001**	−0.001**
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	1454	1454	700	700	754	754
Within R-squared	0.029	0.062	0.019	0.073	0.043	0.076
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household controls		Yes		Yes		Yes
District controls		Yes		Yes		Yes

Notes: The dependent variable is a dummy indicator that takes the value of one if a household uses LPG as the primary cooking fuel. Standard errors are clustered at the household level and reported in parentheses. The sample is composed of all households in columns (1)–(2), and households that received and did not receive intervention in 2017 in columns (3)–(4) and columns (5)–(6), respectively. *** and ** denote statistical significance at the 1 % and 5 % levels, respectively. Household Controls include the age, sex, education, and employment status of the household head as well as the number of household members and electrification of the household. District Controls include whether the community is classified as rural.

controls for household- and district-level covariates. All estimations include household and survey-year fixed effects, denoted as household FE and year FE, respectively.

The coefficients of having children aged under 5 years, income, and distance to refill stations for the treated households reported in columns (3) and (4) of Table 3 are statistically insignificant. These results indicate that households' decisions to use LPG are not associated with these within-variations in their characteristics between 2020 and 2023 among the treated households. LPG users from treated households might have already used LPG because of the intervention in the RLPGPP and they tended to continue to use LPG even if they experienced changes in household conditions, having become familiar with the benefits of LPG use.

For non-treated households, the estimates of having children under the age of 5 years have positive signs in columns (5) and (6) of Table 3. The coefficient in column (6) is 0.145, statistically significant at the 5 % level, suggesting that households with children aged under 5 years have a 34.5 % higher probability of using LPG than households without any children did. Because the variable indicates within-household variation, the estimate captures the effects of newborn children during the period. A plausible explanation for this finding is that households might have had greater incentive to adopt LPG when they had a child to mitigate the adverse health effects of using wood as a cooking fuel. Indoor air pollution has long been recognized for its adverse health consequences, with children being particularly vulnerable owing to their underdeveloped immune systems and lung functions [43,44]. Studies have also shown that clean fuel adoption is associated with lower risk of respiratory illness, burns, and stunting in children as well as improved birth outcomes, including low birth weight [45–48], with increasing advocacy for households with young children and expectant mothers to adopt these fuels. This could make such households more likely to use LPG. In urban India, households with a male first-born child were found to be more likely to use clean fuels [49]. This may be because of the desire to create a healthier living environment for these boys and highlights that Ghanaian households with young children would adopt such actions as using cleaner fuels that would create healthier living conditions for their young children.

Another plausible explanation is a change in the allocation of time within households. Collecting firewood for cooking is typically the primary responsibility of women in Ghanaian households in Ghana [50]. Pregnancy, childbirth, and childcare commitments might have made it difficult to allocate time for wood collection, which might have encouraged the LPG use.

The coefficients of income are statistically insignificant, indicating that the household's decision to use LPG is not associated with within-household income variation, despite income being a positive indicator of LPG adoption, in general, because richer households could pay for LPG equipment and recurring fuel costs and would also have a higher demand for clean air. Our results are in line with those of previous studies that report ambiguous income effects on LPG usage in developing countries (see review in Guta et al. [26]). The ambiguous income effect in developing countries may be attributed to household income not being high enough to cover initial and recurring costs. To further explore this relationship, we estimate the effects by restricting the sample to households that reported the monthly income is higher than the sample mean (3100 Ghanaian cedis in 2023). The results are reported in Table A1 in the appendix. The coefficients of income are positive and statistically significant for non-treated households, indicating that non-treated households with higher incomes are more likely to adopt LPG in response to an increase in their income. This suggests that LPG adoption may occur when household income exceeds a certain threshold, which is consistent with previous findings that LPG use is a non-linear response to household income [51].

The coefficients of the distance to the refill station have negative signs. Longer distances to a station require more time and higher travel costs, which might have led to a decrease in LPG use. These intuitive results suggest that the provision of equipment for the development of refill facilities; in other words, the mitigation of recurrent costs is an important factor in promoting LPG use, as noted in Adjei-Mantey et al. [21]. This suggests that an unstable LPG supply may impede the promotion of LPG use, because it results in higher supplemental costs. In Ghana, a stable supply was provided during 2020 and 2023. A stable LPG supply, however, is often a challenge for some developing countries.

3.3. *Effects of peer influence and safety perception*

Our estimates indicate that having a child boosts LPG adoption among non-treated households that did not receive any equipment under the RLPGPP. The effect may vary depending on the presence of peers (LPG users) in their social network and households' attitudes toward health. For example, the presence of peers in a community may be an incentive to adopt LPG because of reduced psychological burden, increased information sharing, and normative pressure. Additionally, households are likely to adopt LPG if they believe it is safer for their health after the birth of a child.

In this subsection, we further investigate the effect of having a child on LPG usage among non-treated households, based on the presence of peers and the safety perception of LPG. Table 4 presents the estimation results based on Eq. (1). The sample consists of untreated households. All estimations include household and survey-year fixed effects as well as household and district controls.[9]

Column (1) of Table 4 provides the estimate for non-treated households with at least one neighboring household using LPG, whereas column (2) shows the estimated effect for households with zero neighbors using LPG. Similarly, columns (3) and (4) list the estimates for households with more than and less than the mean number of neighboring households, respectively, using LPG.[10] The coefficients of having children are positive and statistically significant in columns (1) and (3). For example, the estimated coefficient in column (1) is 0.189, indicating that households with children aged under 5 years have an approximately 45 % higher possibility of using LPG than households without children aged under 5 years when they have at least one neighboring LPG user. However, the coefficients on having a child are small and statistically insignificant in columns (2) and (4). The findings suggest that non-treated households are likely to adopt LPG when they have a child under 5 years of age, but the effects are specific to households with neighboring LPG users.

The peer effect is associated with the household choice of cleaner cooking fuel because it may encompass the sharing of various types of information, including the availability of equipment, usage method, access to fuel, safety considerations, and overall convenience. This effect is particularly noteworthy in developing countries with limited market access, where clean energy users in acquaintances and social networks play a significant role in their energy choices [11,35,37]. Our findings further suggest the importance of peer effects as a determining factor, indicating that LPG is a viable option when households are subject to peer effects during within-household fluctuations. This corresponds to the findings in the role of peer effects on solar PV adoption [52]. In the context of policy interventions aimed at promoting LPG usage, peer effects are worth considering because they have the potential to enhance the efficiency and effectiveness of interventions.

Column (5) of Table 4 presents the estimate for households that consider LPG a safe fuel for the health of household members, and column (6) represents households that consider it unsafe. The estimates show that the effect of having children on LPG usage is positive and statistically significant for households that consider LPG safe, while it is

[9] When we control for subdistrict fixed effects rather than household fixed effects, there are no significant differences in the estimates. The results are reported in Table A2 of Appendix A

[10] The mean number of peers is 4.24 in our sample.

Table 4
The effect of child presence on LPG usage by peers and household perspectives.

	Peer >0	Peer = 0	Peer high	Peer low	LPG safe	LPG unsafe	Wood bad	Wood good
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Having children aged <5 years	0.189***	−0.076	0.177*	0.022	0.229**	0.035	0.303***	0.018
	(0.067)	(0.159)	(0.094)	(0.072)	(0.092)	(0.082)	(0.089)	(0.081)
Observations	652	102	338	416	354	400	332	422
Within R-squared	0.090	0.306	0.176	0.186	0.228	0.141	0.189	0.149
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable is a dummy indicator that takes the value of one if a household uses LPG as the primary cooking fuel. Standard errors are clustered at the household level and reported in parentheses. The sample is composed of households that did not receive intervention in 2017, and is further divided into households with at least one neighboring household using LPG in column (1) and those with zero LPG usage among neighboring households in column (2). Additionally, there are fewer households with more than the average number of neighboring households using LPG in column (3) compared to the average in column (4). Column (5) represents households that consider LPG as a safe fuel, whereas column (6) represents households that consider it unsafe. Columns (7) and (8) represent households that consider wood fuel as bad and good for health, respectively. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Household Controls include age, sex, education, and employment status of the household head, and number of household members. District Controls include distance to the refill station and whether the community is classified as rural.

insignificant for households that consider LPG unsafe. These results indicate that households increase their use of LPG when they have children; however, the effect is limited to households that consider LPG safe.

Similarly, columns (7) and (8) of Table 4 report the estimates for households that consider wood fuel as bad and good, respectively, for the health of household members. The results indicate that having children increases the probability of using LPG among households who consider that wood fuel is bad for health. Subjective health risks are associated with households' energy choices [53]. Our findings suggest that providing information on the advantages of LPG and the health risks of intrahousehold pollution from solid fuel use is important for policies promoting LPG use.

Overall, the results suggest that the LPG-promoting program (RLPGPP) has led to an increased long-term adoption rate of LPG in both treated and non-treated households. Specifically, non-treated households are more likely to choose the LPG when they have children under 5 years. However, these effects are limited to households with peers (LPG users) in their networks, indicating that the presence of peers may encourage the consideration of LPG as a primary cooking fuel when households have children. This means that the energy transition policy could have a spillover effect through increasing the number of peers (LPG users) and providing direct support to targeted households for LPG adoption in the community. In addition, a household's perception of LPG as a safe energy source for their health is a significant factor in its adoption. This suggests that spreading information on the safety of LPG contributes to its new adoption in the community by increasing the awareness of non-treated households.

3.4. Selection bias from unobservable factors

Our findings suggest that households with children are more likely to use LPG than those without children. However, the estimation results may be subject to bias. For example, households' decisions to have a child and use LPG may be systematically related to unobservable factors, which would reduce the validity of the estimates through selection bias. In this subsection, we test how unobservable factors affect our estimates by providing bias-adjusted estimates proposed by Oster [19], a modification of Altonji et al. [54]. If the influence of unobservable factors is negligible, the adjusted estimates might be close to those of the primary estimations. Conversely, if unobservable variables significantly influence the results, the adjusted estimates might differ.

The test addresses the fluctuations in the coefficient and R-squared when including and excluding covariates, and estimates the bias-adjusted coefficients as follows:

$$\beta^* = \widetilde{\beta} - \delta\left[\overset{o}{\beta} - \widetilde{\beta}\right]\frac{R_{max} - \widetilde{R}}{\widetilde{R} - \overset{o}{R}}, \tag{2}$$

where $\widetilde{\beta}$ and $\widetilde{R}$ are the coefficient and R-squared, respectively, estimated with controls, while β^o and R^o are the coefficient and R-squared, respectively, estimated without controls. β^* is obtained by set R_{max} and δ, which are the parameters depending on the influence of unobservable factors. Oster [19] considered $R_{max} = \Pi\widetilde{R}$ and $\Pi = 1.3$ as the appropriate value. Following her definition, we set Π to 1.3 and then to 1.4 and 1.5 for further strictness of the test. We also set δ to close to 1, which is an appropriate value proposed by Altonji et al. [54] and Oster [19]. Setting δ to 1 means that the observed and unobserved variables are equally related to β^*.

Fig. 3 shows the bias-adjusted effects on the probability of using LPG for the non-treated households, non-treated households with at least one neighboring LPG user, and treated households. The estimated effects were similar to those of the main estimations. Specifically, the bias-adjusted coefficients have the same sign, and the change is not significant for the main results even if we set the strict setting of Π and δ. For example, the estimated coefficient of the bias-adjusted effect for non-treated households with the setting of $\Pi = 1.3$ and $\delta = 1$ is 0.225, while the coefficient in the main estimation is 0.145 (column (6) of Table 3). These results indicate that the estimates in the main analyses are unlikely to be driven by unobserved variables and that selection bias is negligible.

4. Conclusion and policy implications

Indoor air pollution causes social and health concerns, particularly in developing countries where households with various constraints continue to use traditional solid fuels, exposing themselves to substantial social and health risks. This study provides evidence that the RLPGPP, an LPG-promoting program in Ghana, accelerates energy transition in the short term among treated households in Ghana that receive cylinders and cookstoves. Then, 6 years later, LPG usage was extended to untreated households in the program communities that had received no support from the program. This extension is attributed to non-treated households increasing their LPG adoption, particularly in response to having children aged under 5 years. The findings suggest that energy transition policies have had a more substantial impact on clean energy adoption than previously considered, potentially benefiting over 2 billion people worldwide without access to clean fuel [4].

Our estimations show that the effects on non-targeted households are

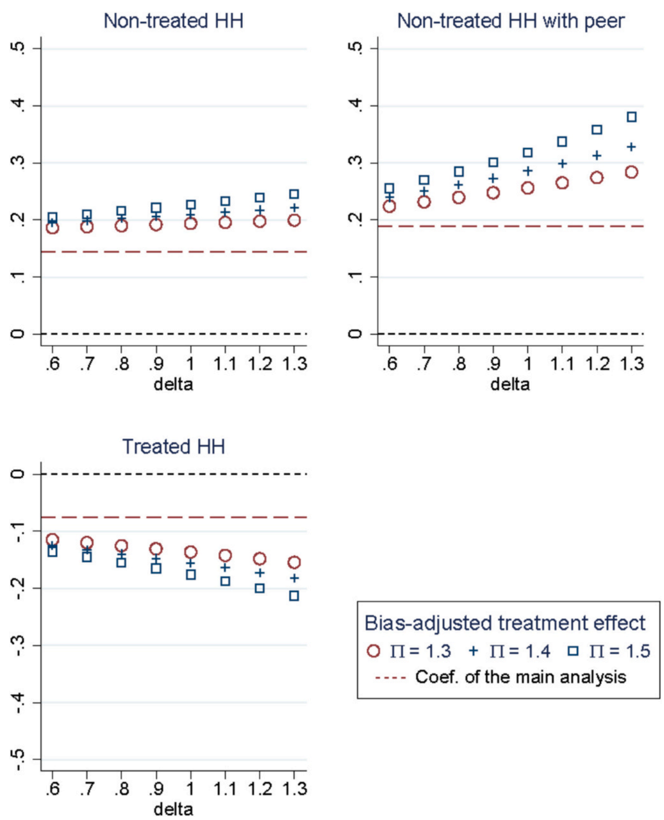

Fig. 3. Bias-adjusted effects considering unobservable variables based on Oster (2019).

limited to having at least one peer in their social network and perceiving LPG as a safe energy source for their health. The findings indicate that energy transition policies could be more effective by intervening through central nodes or using households as social hubs in the community. Social networks and distance are crucial mechanisms for transmitting new agricultural technologies [55], and similar principles can be applied to energy transition policies. These findings imply that energy transition policies can promote household energy transformation with less intervention and funding overall, when considering the role of social networks.

These findings have important policy implications for promoting energy transitions in developing countries. Although the effect of the energy transition policy is well understood [26], its cost-effectiveness has received less attention. Developing feasible and cost-effective policies is essential for facilitating the energy transition of households in developing countries, particularly in Global South countries with limited political and financial resources. This study concludes that the diffusion of LPG cylinders and cookstoves can drive energy transition and is more cost-effective when considering the role of peer effects and information sharing, offering an effective strategy for promoting household energy transitions in Global South countries.

This study has some limitations. The first is a sampling limitation. The analyses informing the findings that LPG adoption can be promoted by providing equipment, and that the peer effect plays an important role in the expansion of promotion in the community were performed based on rounds of surveys conducted in specific districts rather than all districts of the program implementation. This limitation might have constrained the external validity of the findings. Second, several household and district variables were excluded from the estimation models. While our models include possible endogeneity as a control variable and household-fixed effects, unobserved characteristics may still be a concern. We address this issue by estimating the bias-adjusted estimators, showing that the bias is negligible. Future studies should address selection bias.

CRediT authorship contribution statement

Kwame Adjei-Mantey: Validation, Data curation, Conceptualization, Writing – review & editing, Writing – original draft. **Ken'ichi Matsumoto:** Validation, Writing – review & editing. **Tomoki Nakayama:** Project administration, Funding acquisition, Conceptualization. **Peter Quartey:** Validation, Investigation, Data curation. **Yosuke Shigetomi:** Validation, Conceptualization. **Kenji Takeuchi:** Validation, Supervision, Investigation, Data curation. **Yuki Yamamoto:** Visualization, Validation, Resources, Methodology, Funding acquisition, Formal analysis, Conceptualization, Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that may have influenced the work reported in this study.

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Appendix A

Table A1
The effects of within-household variations on LPG usage for higher income households.

	All		Treated households		Non-treated households	
	(1)	(2)	(3)	(4)	(5)	(6)
Having children aged <5 years	0.109	0.102	0.031	0.001	0.216**	0.226*
	(0.071)	(0.072)	(0.099)	(0.102)	(0.097)	(0.116)
ln(income)	0.155**	0.159**	0.101	0.085	0.174***	0.224***
	(0.050)	(0.069)	(0.092)	(0.103)	(0.047)	(0.061)
Distance to station	−0.001	−0.001	0.002	0.001	−0.000	−0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	488	488	238	238	250	250
Within R-squared	0.078	0.162	0.064	0.149	0.139	0.244

(continued on next page)

Table A1 (*continued*)

	All		Treated households		Non-treated households	
	(1)	(2)	(3)	(4)	(5)	(6)
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household Controls		Yes		Yes		Yes
District Controls		Yes		Yes		Yes

Notes: The dependent variable is a dummy indicator that takes the value of one if a household uses LPG as the primary cooking fuel. Standard errors are clustered at the household level and reported in parentheses. The sample is restricted to households with higher income (the reported monthly household income is higher than the sample mean of 3100 Ghanaian cedis in 2023). The estimates are reported for all households in columns (1)–(2), and households that received and did not receive intervention in 2017 in columns (3)–(4) and columns (5)–(6), respectively. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Household Controls include the age, sex, education, and employment status of the household head as well as the number of household members and electrification of the household. District Controls include whether the community is classified as rural.

Table A2
The effect of child presence on LPG usage using subdistrict fixed effects.

	Peer >0	Peer = 0	Peer high	Peer low	LPG safe	LPG unsafe	Wood bad	Wood good
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Having children aged <5 years	0.118**	−0.159	0.154**	−0.005	0.122*	0.055	0.128*	0.046
	(0.047)	(0.137)	(0.065)	(0.052)	(0.066)	(0.054)	(0.068)	(0.072)
Observations	652	102	338	416	354	400	332	422
Within R-squared	0.090	0.306	0.176	0.186	0.228	0.141	0.189	0.149
Subdistrict FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable is a dummy indicator that takes the value of one if a household uses LPG as the primary cooking fuel. Standard errors are clustered at the household level and reported in parentheses. The sample is composed of households that did not receive intervention in 2017, and is further divided into households with at least one neighboring household using LPG in column (1) and those with zero LPG usage among neighboring households in column (2). Additionally, there are fewer households with more than the average number of neighboring households using LPG in column (3) compared to the average in column (4). Column (5) represents households that consider LPG as a safe fuel, whereas column (6) represents households that consider it unsafe. Columns (7) and (8) represent households that consider wood fuel as bad and good for health, respectively. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Household Controls include age, sex, education, and employment status of the household head as well as the number of household members. District Controls include distance to the refill station and whether the community is classified as rural.

Appendix B. Questionnaire in 2023

District Code……………… Enumeration Area Code/Name ………………..
Community Name ………………………… House Number (if available) …………………….

Location: [1] Rural [2] Urban Record household GPS address: ………………….
Date of Interview ………………… Interviewer's Name ………………………………

UPPER CASE LETTERS INDICATE INSTRUCTIONS FOR INTERVIEWERS. YOU WILL FIND THEM IN RED COLORED LETTERING

Lower case letters indicate questions and information to be read to the interviewee or respondent.

THE PRIMARY RESPONDENT SHOULD BE THE HOUSEHOLD HEAD; IN HIS/HER ABSENCE, THE HEAD'S SPOUSE OR AN ADULT HOUSEHOLD MEMBER MAY BE INTERVIEWED IN THAT ORDER.

INTRODUCTION

Hello, I am_________________, an enumerator from the [anonymous] assisting in data collection for an ongoing research by [anonymous]. We are interviewing households on cooking fuels. We will interview about 800 households in different districts in this region this time. We conducted interview with 900 households in 2020, and now we would like to interview you as a part of follow-up survey. The aim of the research is to understand all issues surrounding the acceptance and use of LPG with the hope that findings will ultimately improve the implementation of policies on cooking fuels. This interview is expected to take between 45-50 minutes. Participation in this survey is voluntary and this survey will be answered with your agreement, but you can quit answering the question at any time if you do not want to continue. Please note that information you provide will be treated with utmost confidentiality and not be linked back to you in any way for any reason whatsoever.

NOTE: If THE RESPONDENT'S AGREEMENT IS CONFIRMED → GO TO SECTION A.

SECTION A: HOUSEHOLD HEAD/PRIMARY COOK CHARACTERISTICS

Please tell me a few things about the head of this household.

Part 1: Household Head

1. Gender [0] Female [1] Male
2. Age [0] <25 [1] 26-35[2] 36-45[3] 46-55[4] >55
3. Level of education <u>completed</u> [0] None [1] Primary [2] JSS/Middle School [3] Secondary/Vocational/Technical [4] Tertiary
4. Employment status
   [0] Unemployed [1] Employed [2] Self-employed [3] Retiree
5. If working, what is your main occupation/current job
   a. Agricultural worker ……….
   b. Construction/factory/by-day worker ………….
   c. Skilled artisan …………….
   d. Self-employed (non-agricultural) ……………….
   e. Employed in informal sector non-farm enterprise ………….
   f. Civil/Public servant ……………
   g. Employed in formal private sector enterprise ………….
   h. Other (Please state) ……………………………………..
6. Is the primary cook different from the HH head? [0] No [1] Yes

ANSWER TO Q.6 IS "NO" → SECTION B
ANSWER TO Q.6 IS "YES" → PART 2

Part 2: Primary cook (SKIP "Part 2" IF PRIMARY COOK IS THE SAME AS HOUSEHOLD HEAD)

7. Gender [0] Female [1] Male
8. Age [0] <25 [1] 26-35[2] 36-45[3] 46-55[4] >55
9. Level of education <u>completed</u> [0] None [1] Primary [2] JSS/Middle School [3] Secondary/Vocational/Technical [4] Tertiary
10. Employment status
    [0] Unemployed [1] Employed [2] Self-employed [3] Retiree

SECTION B: COOKING FUEL USE AND RELATED ISSUES

11. Did you receive LPG cylinder (with/without cookstove) from the local government about 7 years ago? [0] No [1] Yes

ANSWER TO Q.11 IS "YES" → Q.12
ANSWER TO Q.11 IS "NO" → Q.18

12. What was the primary cooking fuel used in this household before receiving the LPG equipment from the government in 2016?
    [0] Firewood [1] Charcoal [2] LPG [3] Other (Please state) ………
13. Did you own LPG cylinder and cookstove prior to receiving the government supplied one?
    [0] No [1] Yes
14. Do you still have the full package of LPG equipment you received in 2016?
    [0] No [1] Yes

ANSWER TO Q.14 IS "YES" → Q.16
ANSWER TO Q.14 IS "NO" → Q.15

15. What has happened to [the parts of] the equipment and accessories received in 2016?
    [0] I/We gave them out as a gift [1] Missing or stolen [2] I/We sold them
    [3] Other (Please state) ………………………………………………………………………..

16. Have you ever used the LPG equipment [received in 2016] for cooking? [0] No [1] Yes

ANSWER TO Q.16 IS "YES" → Q.18
ANSWER TO Q.16 IS "NO" → Q.17

17. Why you have never used it? Please choose the most important reason.

[0] I don't know how to use it
[1] I think it is not safe to use as it can lead to fire outbreaks
[2] It does not cook food as well as the other fuel(s) I use
[3] I think it is not good for one's health to eat food cooked with LPG
[4] I had my own LPG equipment before receiving the one from government
[5] Other (Please state) ………………………………………………………………………..

18. How many times do you usually cook in a day? [0] No cooking [1] 1 x [2] 2 x [3] 3x [4] >3x

19. What are the main types of cooking fuel <u>currently</u> used in this household in order of importance?
1st choice: [0] Firewood [1] Charcoal [2] LPG [3] Other (Please state) ………
2nd choice: [0] Firewood [1] Charcoal [2] LPG [3] Other (Please state) ……… [4] Not applicable (Household uses only one type of fuel)
3rd choice: [0] Firewood [1] Charcoal [2] LPG [3] Other (Please state) ……… [4] Not applicable (Household uses only two types of fuel)

20. What was the main cooking fuel used before the coronavirus pandemic?
[0] Firewood [1] Charcoal [2] LPG

ANSWER TO Q.19 INCLUDES "FIREWOOD" → Q.21
ANSWER TO Q.19 DOES NOT INCLUDE "FIREWOOD" → Q.22

21. Who usually collects firewood for this household?
[0] Female adult (15 years+) [1] Male adult (15 years+)
[2] Female child (Under 15 years) [3] Male child (Under 15 years)

22. How much of the following cooking fuels do you use in one week?
(ASK ONLY FOR THOSE FUELS THAT APPLY FROM Q.19)

a. Charcoal: Ghc……………(weight ………… kg) per week
b. Firewood: Ghc……………(weight ………… kg) per week (if household buys).

If household does not buy, use (i) below to help estimate:

i. What is the weight of firewood used per week? (You may relate to any of the following)
[0] up to 10 kg (10kg=the equivalent of 2 baby sack bags of rice)
[1] between 10kg and 25kg (25kg= the equivalent of ½ bag of rice)
[2] between 25kg and 50 kg (50kg=the equivalent of a bag of cement)
[3] between 50kg and 100kg (100kg=the equivalent of 2 bags of cement)
[4] more than 100kg (equivalent to more than 2 bags of cement)

c. Kerosene: Ghc……………(weight ………… kg) per week

ANSWER TO Q.19 INCLUDES "LPG" → Q.23
ANSWER TO Q.19 DOES NOT INCLUDE "LPG" → Q.28

23. How many times in a day do you usually use your LPG?
[0] 1x [1] 2x [2] 3x [3] >3x

24. On average, how long does it take to run out of gas after filling your cylinder? …….. weeks

25. How many times have you refilled your cylinder since you first received it? ……………..

26. What is the size of your cylinder? ……………kg

27. How much does it cost for a single refill of your cylinder? Ghc ……………..

28. How long does it take to make a return trip to the nearest LPG refill station? (Travel time only) ...…… minutes

29. By what means would you make this trip?
[0] On foot [1] Bicycle [2] Motor bike [4] Car
[5] Other (Please state)…………………………

30. In the past 7 days, which fuel have you used more? [0] Firewood [1] Charcoal [2] LPG

31. How long does it take to make a return trip to the nearest forest or place where one can gather firewood? (Travel time only. Do not include time spent collecting the firewood) ………… minutes

32. By what means would you make this trip?
[0] On foot [1] Bicycle [2] Motor bike [4] Car
[5] Other (Please state) …………………………

Please tell me how much you agree or disagree with the following statements about cooking fuels.

33. Firewood or charcoal use has negative health implications on the user
[1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree

34. LPG use is safer for one's health compared to other cooking fuels
[1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree

35. Food cooked with LPG tastes better than food cooked with other fuels
[1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree

36. Using firewood or charcoal to cook takes a lot more time than I can afford
[1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree

37. Exclusive use of LPG by all households nationwide should be promoted and enforced
[1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree

Please tell me how much you agree or disagree with whether the following serve as constraints/disadvantages to you in using or an attempt to use LPG exclusively or as your primary fuel.

38. Gas is too expensive
    [1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree
39. Gas is often in short supply
    [1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree
40. Refill station is not easily accessible/ distance to refill station too long
    [1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree
41. I'm skeptical about how safe it is relative to LPG's potential to cause fires or harm my family
    [1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree

42. Please share your opinion or anything you want to say about the Rural LPG Promotion Program, RLPGPP (the RLPGPP is the government funded program which enabled some households to receive the cylinder and cookstoves for free in 2016). SKIP IF THEY ARE NON-BENEFICIARIES WHO DO NOT KNOW ABOUT THE PROGRAM
    ………..
    ……
    ……
    ……
    ……

43. Among 10 close associates (friends, neighbors, relatives), about how many of them use LPG? …………

44. What are the occupations/positions in the society of those who use LPG in Q.43? (Select all that apply).
    School teacher ………..
    Health worker ……………
    Religious leader (pastor/church elder/imam/traditional priest, etc) ……………
    Government worker (civil/public servant) ……………..
    Other (Please state) …………………………..

SECTION C: STATED PREFERENCE

Let's assume for a moment that there is a service which is akin to refilling your LPG cylinder for you 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.

45. What is the maximum amount per delivery (aside the cost of the gas) you will be willing to pay as the fee for this service each time you use it? LET RESPONDENTS INDICATE THE AMOUNT THEY ARE WILLING TO PAY AND ENTER SAME. IF THEY CHOOSE AN ODD AMOUNT, ASK THEM TO CHOOSE BETWEEN THE NEAREST EVEN AMOUNT BELOW OR ABOVE THEIR INITIAL CHOICE
    [0] Ghc 0.00 [1] Ghc 2.00 [2] Ghc 4.00 [3] Ghc 6.00 [4] Ghc 8.00 [5] Ghc 10.00 [6] Ghc 12.00 [7] Ghc 14.00 [8] Ghc 16.00 [9] Ghc 18.00 [10] Ghc 20.00 [11] More than Ghc 20.00 (Please state) ………………….

46. Please tell me how much you agree or disagree with the following statement:

    This system will increase my likelihood of using LPG exclusively/as my primary cooking fuel
    [1] Strongly agree [2] Agree[3] Neutral [4] Disagree [5] Strongly disagree
47. Which of these options would you prefer?
    [1] Invest in a business where you won't lose money but will make low profits
    [2] Invest in a business where there is a small chance you will lose money but will potentially make high profits
48. Which of these options would you prefer?
    [1] Receive 20 Ghana cedis today [2] Receive 30 Ghana cedis in one month

ECTION D: GENERAL HOUSEHOLD INFORMATION

49. How much does your household spend averagely every month on the following?
    a. Food: Ghc ……………….
    b. Liquor/tobacco: Ghc …………….
    c. Clothing/footwear: Ghc ……………
    d. Rent: Ghc ……………..
    e. Health expenses (hospital visits, buying drugs, etc): Ghc ……………..
    f. Education expenses (buying books, stationery, etc for children's school needs) Ghc ……..
    g. Transportation (fuel for own vehicle, public transport fares): Ghc ………………..
    h. Communication: (airtime, data bundles, etc): Ghc ………………..
    i. Electricity bill: Ghc ……………..
    j. Water bill (or water costs if the household buys their water): Ghc …………………
    k. Gas: Ghc …………………
    l. Kerosene: Ghc ………………….
    m. Charcoal: Ghc ……………….
    n. Other cooking fuel: Ghc ………………..
    o. Personal and home care (barbering/hair dressing, toiletries, etc): Ghc ………………
    p. Miscellaneous: Ghc …………………

50. What is the total number of persons in this household? …………………………
51. How many household members are children aged 15 or younger? …………………….
52. How many household members are children aged 5 or younger? ………………………
53. How many household members are working? …………………….
54. Are your children aged 15 or younger enrolled in school?
    [0] No [1] Yes [2] N/A (household has no children within this age group)

    ANSWER TO Q.54 IS "YES" → Q.55
    ANSWER TO Q.54 IS "NO" OR "N/A" → Q.58
55. How regularly do they go to school in a typical week?
    [0]20% of the time [1]40% of the time [2] 60% of the time
    [3] 80% of the time [4]100% of the time
56. How long does it take to make a round trip to the school your children attend? (Travel time only) ………….. minutes
57. By what means do they make this trip?
    [0] On foot [1] Bicycle [2] Motor bike [4] Car
    [5] Other (Please state) …………………………
58. Is your household connected to electricity? [0] No [1] Yes
    ANSWER TO Q.58 IS "YES" → Q.59
    ANSWER TO Q.58 IS "NO" → Q.60
59. Which of these different light bulbs do you use with the electricity? Choose all that apply
    [1] Incandescent bulb [2] Fluorescent tube (with choke) [3] Compact fluorescent light (CFL) bulb [4] LED light bulb [5] other
60. Do you watch TV or listen to the radio regularly in this household? [0] No [1] Yes
61. Does any household member have an account with a bank, S&L, or a micro finance institution?
    [0] No [1] Yes
62. Has any member of this household ever contracted a loan from a financial institution or cooperative society, etc? [0] No [1] Yes
63. Do you think any adult member of this household would be able to get a loan from a bank, other financial institution, cooperative society or from friends/relatives if they applied for one? [0] No [1] Yes
64. How much income accrues to this household every month from all members from the following? (FOR EACH CATEGORY, ADD UP THE AMOUNTS EACH HOUSEHOLD MEMBER EARNS)
    a. Wages/Salaries: Ghc ………………….
    b. Rent income: Ghc ……………………..
    c. Agricultural/farm income: Ghc …………………
    d. Income from non-farm enterprise: Ghc ………………….
    e. Remittances: Ghc ……………………..
    f. Miscellaneous: Ghc …………………….
65. Has any member of this household suffered persistent cough, cold, other symptom of respiratory illness or itchy or teary eyes in the past 2 weeks? [0] No [1] Yes
66. Has any member of this household ever contracted a respiratory or any heart related health condition in the past? [0] No [1] Yes
67. How many times did you wash your hands with soap under running water [for about 20 seconds] yesterday? [0] Never did [1] 1-2 times [2] 3-5 times [3] more than 5 times
68. Is there a functioning health facility in this community? [0] No [1] Yes
69. How long does it take to make a round trip to the nearest health facility? (Travel time only. Do not add time spent at the facility) …………….. minutes
70. By what means would you make this trip?
    [0] On foot [1] Bicycle [2] Motor bike [4] Car
    [5] Other (Please state) …………………………
71. How many hours do members of this household spend cooking per day?
    [0] None [1] 0.5-1 h [2] 1-2 h [3] 2-3 h [4] 3-4 h [5] >5 h
72. What type of cooking place do members of this household "primarily" use?
    [0] In dwelling, NOT in sleeping area [1] In dwelling, in sleeping area
    [2] IN a separate dwelling [3] In a veranda (roofed platform with at least two open sides)
    [4] Outdoors [5] Other [6] No cooking
73. What type of cooking place do members of this household "secondarily" use?
    [0] In dwelling, NOT in sleeping area [1] In dwelling, in sleeping area
    [2] IN a separate dwelling [3] In a veranda (roofed platform with at least two open sides)
    [4] Outdoors [5] Other [6] Do not have second kitchen
74. What percentage of time do members of this household use the primary cooking place/kitchen (Q.72) out of total cooking time?
    [0] 100% [1] 90% [2] 80% [3] 70% [4] 50-70%
75. Does any member of this household smoke (tabaco/ cigarette)? [0] No [1] Yes
76. What do you think is the "most" important source of outdoor air pollutants (such as PM2.5) in your area/region during Harmattan (dry) season?
    [0] Residential cooking [1] Residential waste burning [2] Fumes from vehicles [3] Grass/shrubs burning for clearing before farming [4] Crop residue burning after harvesting [5] Natural forest burning [6] Saharan desert dust

77. What do you think is the “second most” important source of outdoor air pollutants (such as PM2.5) in your region during Harmattan (dry) season?
[0] Residential cooking [1] Residential waste burning [2] Fumes from vehicles [3] Grass/shrubs burning for clearing before farming [4] Crop residue burning after harvesting [5] Natural forest burning [6] Saharan desert dust

78. What do you think is the “most” important source of outdoor air pollutants (such as PM2.5) in your region during NON-Harmattan (wet) season?
[0] Residential cooking [1] Residential waste burning [2] Fumes from vehicles [3] Grass/shrubs burning for clearing before farming [4] Crop residue burning after harvesting [5] Natural forest burning [6] Saharan desert dust

79. What do you think is the “second most” important source of outdoor air pollutants (such as PM2.5) in your region during NON-Harmattan (wet) season?
[0] Residential cooking [1] Residential waste burning [2] Fumes from vehicles [3] Grass/shrubs burning for clearing before farming [4] Crop residue burning after harvesting [5] Natural forest burning [6] Saharan desert dust

This is the end of the interview. Thank you for your time.

Would you mind if we come to you for a similar interview in the future? [1] No [2] Yes

SUPPLY SIDE QUESTIONS (FOR SUPERVISORS ONLY)

1. Did this refill station ever experience gas shortage over the past 3 months? [0] No [1] Yes
2. Does this refill station offer additional services besides fuel sale? (repair of cylinders, sales of groceries, etc) [0] No [1] Yes
3. How does sales of LPG now compare to the covid-19 pandemic period? [0] Increased now [1] Decreased now [2] Not changed [999] Don’t know
4. Record GPS address of refill station location. …………………………..

Data availability

Data will be made available on request.

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