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Estimating the spill-over impacts of a clean cooking fuel program: Evidence from Ghana

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ABSTRACT

Transition to cleaner cooking fuels is a key challenge for sustainable development. This study evaluates the spill-over impact of a program that distributes liquefied petroleum gas (LPG) cylinders and accessories for free on cooking fuel choice and poverty alleviation in Ghana. We construct a district-level dataset based on the Ghana Living Standards Surveys 6 and 7, collected before and after the program implementation, respectively. Using difference-in-differences combined with matching techniques, we find that the program had no significant spill-over impacts on primary household cooking fuel; LPG use did not increase and firewood use did not decrease among rural households in treated districts. However, there is a possible association between the program and poverty reduction in treated districts, and the likely channel is investments in refill stations. The results suggest that the program should refine its implementation strategy to yield substantial effects on cooking fuel choice. In addition, implementing the program with the right infrastructure in place could increase the benefits associated with it.

1. Introduction

Household air pollution is responsible for 3.8 million premature deaths in the world every year [30]. The risk is particularly high in developing countries, where many households use traditional solid fuels (e.g., wood, crop waste, charcoal, coal, and dung) for cooking. In addition to mortality risk, exposure to household air pollution increases the risk of contracting respiratory and cardiovascular diseases and other health effects, such as child stunting and detrimental cognitive effects in children including lower verbal ability and lower school readiness [1,21,27,30]. The promotion of clean cooking fuels continues to be a challenge for many countries in their quest for sustainable development.

The governments of various countries have set ambitious targets for the adoption of clean cooking fuel to reduce exposure to household air pollution and its adverse effects. For example, Peru, South Africa, and Ghana, among other countries, have committed to such targets by implementing interventions for cleaner cooking. In Ghana—the focus of this study—the Strategic Plan on Energy was drafted in 2010 to ensure that 50% of households have access to liquefied petroleum gas (LPG) by 2015. The Ghana Sustainable Energy for All action plan was drawn up to implement several measures for attaining the clean cooking agenda. One such measure is the Rural Liquified Petroleum Gas Promotion Program (RLPGPP), which aims to accelerate the uptake of LPG in rural communities. The program distributes filled LPG cylinders and cookstoves with complementary accessories for free to selected rural households.

The free distribution of LPG equipment is expected to reduce firewood use and increase the use of clean cooking fuel among rural residents by removing initial costs for households to switch to LPG use. Karimu et al. [17] have argued that initial costs could be prohibitive for some households, thereby preventing them from transitioning to cleaner cooking fuel. Thus, the RLPGPP is expected to reduce reliance on firewood as the primary cooking fuel of rural residents. Furthermore, reduced firewood use may lead to poverty alleviation through multiple channels. First, less dependence on firewood leads to less exposure to household air pollution. Consequently, there will be less incidence of related illnesses, which may increase the number of productive days. Second, the time spent on collecting firewood from bushes and forests is reduced. The time saving could increase economic or income-generating activities, and therefore, could reduce poverty.

This study aims to evaluate the impact of the RLPGPP on primary cooking fuel choice. The program has been implemented for several years, but its achievement at the nationwide level has yet to be assessed. As the main goal of the program was to aid the transition to clean cooking fuel, it is essential to evaluate the program by assessing whether its objectives are fulfilled and whether the allocation of limited resources is justifiable. The program distributed free LPG equipment to

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a limited number of households in each district. Our goal is to evaluate the effect of the program at the district level through the peer effect. In other words, we examine whether benefiting from the program leads to fuel switching for beneficiaries and non-beneficiaries in the same district through the peer effect. By peer effect, this study refers to households learning from their peers or other households within the same geographical area to decide switching to LPG because of the influence of their peers or the rest of the community on them. Bonan et al. [9], for instance, provided evidence that social interaction and imitation within communities can promote the adoption of improved cooking technology even among non-beneficiary households of a clean cooking intervention. In this study, we also examine whether any unintended impacts have resulted from the program. Specifically, we measure the potential effects on poverty reduction.

We focus on Ghana's RLPGPP because of the uniqueness of its program design. First, it distributes all equipment for clean cooking free of charge. Programs implemented in other countries differ in this respect. In India, for example, loans are used to provide cookstoves to households that need them [14], while in Peru, vouchers to buy LPG cylinders are offered [10,24]; in both cases, households are expected to purchase cookstoves themselves. These approaches may reduce the effectiveness of the support provided to households to switch to clean cooking fuel, as the initial costs of switching may be the main obstacle. Second, the RLPGPP focuses on the promotion of LPG in rural areas, where program implementation could be challenging owing to the limited access to refill stations. Thus, there are significant implications if the RLPGPP has achieved success under these conditions. It appears to be difficult for rural residents to shift to exclusive LPG use or even combined fuel use, although they have access to a government-assisted program [19]. A study by Andadari et al. [6] included samples from both rural and urban households in Indonesia and found that medium to high-income households in urban and suburban areas benefited the most. As these households were likely using LPG even before the program, the subsidized LPG price would have resulted in greater savings for them than for people in rural areas. Owing to the limited scope of analysis by previous studies, it is still unclear how rural households respond to these programs in terms of their cooking fuel choice after the program implementation. Our study's focus on rural households across the country provides insight into the impacts of such policies in areas where infrastructure for refilling the gas cylinder is not easily available, and natural resources for conventional fuels are abundant.

Previous evaluation of the RLPGPP in Ghana is scant. Asante et al. [7] used data collected from late 2015 to 2016 from five communities in the Nkoranza North District and revealed that the RLPGPP had not achieved its stated goal in the district. The study showed that more than half of beneficiaries had not once refilled their cylinders in the nine months after they received them, while less than 10% of beneficiaries in those communities were still using LPG about 18 months after the program's implementation in their communities. The study also found that all surveyed respondents in the communities continued to use fuelwood as their primary cooking fuel, despite benefiting from the program. Adjei-Mantey et al. [4] examined the effect of the RLPGPP in two districts in the Greater Accra Region and found a positive impact on fuel choice. The study showed a 23% increase in the likelihood of using LPG as main fuel among beneficiary households. The studies of Asante et al. [7] and Adjei-Mantey et al. [4] on the RLPGPP in different districts show mixed results. As these studies are based on evaluations of specific districts, an assessment of the program using nationwide data is necessary to draw firm conclusions about the program's impact.

This study's contribution can be summarized as follows. Although some studies explore the impact of similar programs in developing and emerging market economies [6,10,14,18,24], there is little evaluation of the policy at the nationwide level. The studies of Asante et al. [7] and Adjei-Mantey et al. [4] on the RLPGPP in different districts show mixed results. As these studies are based on evaluations of specific districts, an assessment of the program using nationwide data is necessary to draw firm conclusions about the program's impact. This study contributes to the literature by using data that cover the entire country and employs a thorough methodology to capture the impacts of the program. Furthermore, while such programs as the RLPGPP have the potential to reduce poverty, studies that empirically test the poverty impacts are scarce. Previous fuel switching program evaluation studies tested the effects of the programs on other variables such as respiratory conditions, kitchen concentrations of $PM_{2.5}$, and infant mortality in the household [10,15,24,25]. However, effects of such programs on poverty have not been well examined. We contribute to the literature by filling this research gap and providing evidence from empirical data on the fuel transition program's impact on poverty reduction. Foell et al. [11] also argued for the need to better understand the use of incentives to promote fuel switching for the sake of evidence-based policies. Our study contributes to meeting this need by investigating the RLPGPP's effects on both fuel choices and poverty.

2. Ghana's Rural LPG Promotion Program

The Ghanaian government's attempts to promote LPG can be traced back to the early 1990s. In 1990, the government introduced the LPG Promotion Program to prevent forest depletion and reduce dependence on fuelwood as the primary cooking fuel. The program, however, was limited to households and public service providers of food catering in a few towns within urban centers [5]. Strategies under these programs included the free distribution of LPG cylinders to beneficiaries, the establishment of the Ghana Cylinder Manufacturing Company (GCMC) in 1998 to produce standardized equipment at affordable prices, and the establishment of an LPG fund financed by levies on LPG purchases.[1] While the GCMC is still in operation and has played an active role in the RLPGPP, most of the earlier programs are no longer in operation. The subsidies on LPG that replaced the levy to incentivize LPG adoption were subsequently abolished as part of a broader agenda to remove subsidies on all petroleum products for fiscal and economic stability. Latest statistics from the most recent population and housing census conducted in 2021 indicate that across the country, LPG is used in 36.9% of households. However, in rural areas, the LPG penetration rate is extremely low – standing at 14.8% [12].

In 2013, the Ministry of Energy started the pilot phase of the RLPGPP. The main aim of the program is to accelerate the uptake of LPG and make it the primary cooking fuel in rural communities. A selected household in a beneficiary district is given a one-time filled LPG cylinder and cookstove with complementary accessories to switch from dirty cooking fuels. The switch to LPG requires initial set-up costs, including the costs of LPG cylinders or canisters, cookstoves, gas hoses, and gas regulators, even before the fuel itself is purchased. These costs are deemed prohibitive for some households, making them reluctant to change their cooking fuel. As suggested by the findings from previous studies (e.g., [16,17,20]), income level is positively correlated with the choice of LPG among Ghanaian households, indicating the potential influence of the ability to pay in fuel choice decisions. Thus, by eliminating these initial costs through the free distribution of equipment, the ministry expected households to switch their primary cooking fuel to a cleaner one, and consequently, LPG penetration would increase. However, it remains to be examined whether this has happened sufficiently to yield significant spill-over effects on fuel choices among rural households.

As part of the program, the ministry aimed to facilitate the setting up of mini refill outlets in every beneficiary district in collaboration with LPG marketing companies to make refill options available to beneficiaries. This was important because, in Ghana, households must carry their LPG cylinders or canisters to an LPG refill station whenever they are out

[1] The government later removed levies and introduced subsidies for domestic LPG users.

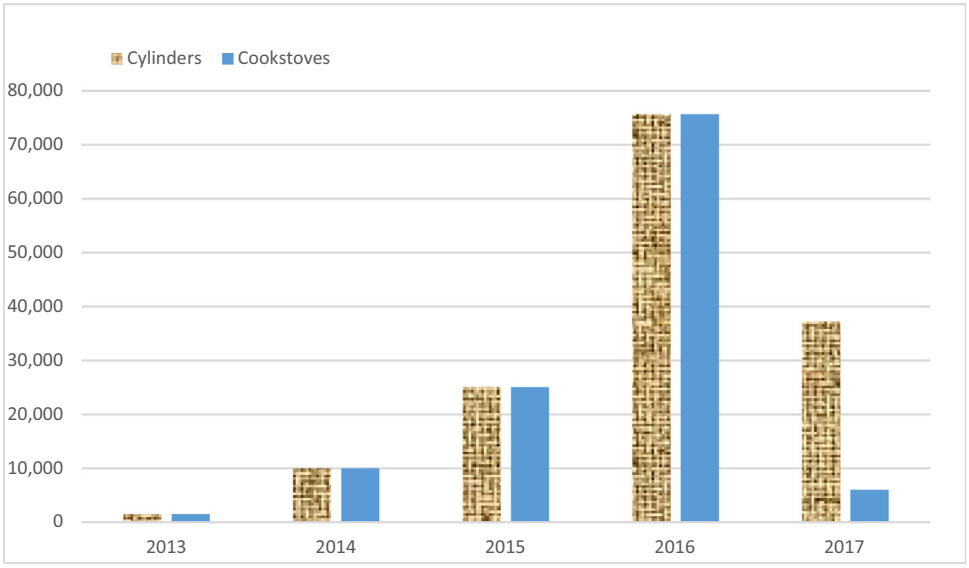

Fig. 1. Amount of LPG equipment distributed under the RLPGPP.

of cooking gas for a refill. Hence, the presence of refill stations is crucial to the overall success of the program. The equipment distribution started in December 2013 and continued until the end of the third quarter of 2017. Documents from the Ministry of Energy, as well as key informant interviews by the authors, reveal that beneficiary districts were selected based on poverty levels, their location (i.e., rural or urban), and the level of deforestation.

Fig. 1 shows the number of LPG cylinders and cookstoves distributed up to 2017 under the program.[2] By the end of 2017, 149,500 6-kg sized[3] cylinders and 118,360 single-burner cookstoves with accessories, including gas regulators and gas tubes, had been distributed in 50 beneficiary districts across the country.[4] Between 1,000 and 5,500 cylinders and accessories had been distributed to households in treated districts with the mean number of cylinders and accessories per district at 1,720. As shown in the figure, more than half of the total distributions occurred in 2016.

Source: Ghana's Ministry of Energy [22]

Note: In 2017, the contracted producer could not supply the required cookstoves according to schedule. Consequently, the ministry decided to go ahead with the distribution of cylinders to beneficiary districts and send the cookstoves later upon delivery by the supplier.

The framework of our hypothesis is summarized in Fig. 2. The implementation of the RLPGPP in any district should increase LPG use as primary cooking fuel. Therefore, it will reduce the use of dirty fuels, such as firewood and charcoal. Moreover, these changes in fuel choice could eventually lead to poverty reduction through improved health, labor force participation, and productivity [1,23]. Less firewood use reduces the time spent on firewood collection, which increases the time available for firewood collectors to devote to economic activities, thereby reducing poverty and enhancing wellbeing. Similarly, reduced firewood usage lowers exposures to household air pollution, consequently leading to reduced occurrence of related illnesses. This increases healthy days and productivity, thereby reducing poverty.

3. Data and empirical methodology

3.1. Data

This study used the two most recent rounds of the Ghana Living Standards Survey (GLSS 6 and GLSS 7). GLSS 6 data were collected from late 2012 to late 2013, with data collection ending just three months before the roll-out of the RLPGPP. The survey contains data from over 9327 rural households covering every district in the country. GLSS 7 data were collected from late 2016 to late 2017 for 7,991 rural households from all but one district across the country. These independent cross-sectional nationwide surveys collected data for different households at different periods. We constructed district-level data by combining these datasets. We assigned each district a unique code for both periods and computed district averages for the variables of interest. We did this for both rounds of the data to obtain data at the baseline and end line. As GLSS data provided the exact date on which a household was interviewed, we can divide districts into treated and control districts by referring to the data from Ghana's Ministry of Energy on the exact month and year in which beneficiaries received LPG equipment in each district.

Treated districts are those that benefited from the program before they were surveyed in the GLSS 7, while control districts did not benefit at the time of the survey. The proportion of households in a district that uses LPG as their primary cooking fuel was employed as a response variable to assess the impact of the RLPGPP. This is because the main goal of the program is to increase LPG usage among households, particularly in rural areas. Notably, fuel stacking or use of multiple fuels is usual in Ghana. The survey, recognizing this fact, requested respondents to state which fuel was their main or primary cooking fuel in the household. By using district-level data, which account for all households in the district within the sample, the treatment effect can be viewed as spill-over impacts of the program. As further analysis, we also used the proportion of households in the district living in poverty and extreme poverty as an outcome variable to measure the unintended likely impacts of the program. Poverty (extreme poverty) is defined by upper (lower) poverty lines—Gh¢1,314 (Gh¢792) for 2013 and Gh¢1,760 (Gh¢982) for 2017.[5]

[2] In the last quarter of 2017, the government of Ghana announced that it was considering a cylinder exchange program for LPG users as a household cooking fuel policy. Consequently, no further distributions were made under the RLPGPP after 2017 to prepare for the new policy.

[3] Different cylinder sizes are available on the Ghanaian market and households that choose LPG typically purchase a cylinder size that fits their budget and/or family size. The cylinders distributed under the RLPGPP are 6-kg cylinders.

[4] Districts make up the second sub-administrative level in Ghana. The country creates new districts occasionally to facilitate local governance by splitting existing districts or re-demarcating their boundaries. Consequently, the total number of districts in the country in the pre-intervention period differs from that in the post-intervention period. In this study, new districts created after the pre-intervention period are counted as part of the district from which they were carved.

[5] The average exchange rates were $1:Gh¢2.07 for 2013 and $1:Gh¢4.4 for 2017.

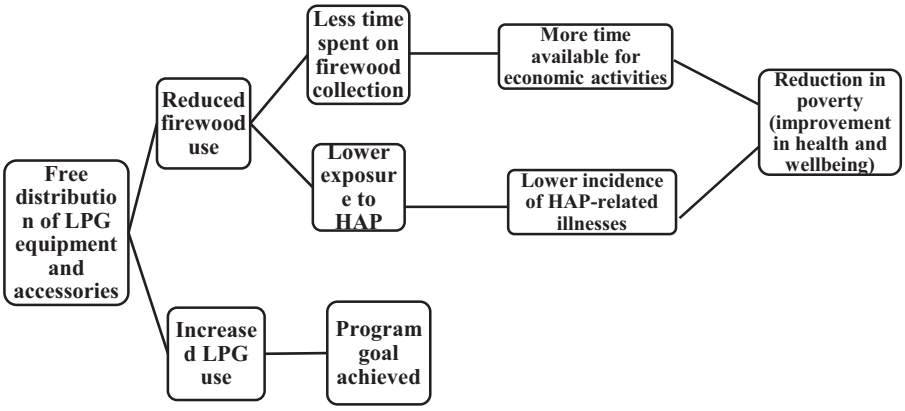

Fig. 2. Framework of the study. Note: HAP stands for household air pollution.

Note: HAP stands for household air pollution.

Table 1
Summary statistics.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
LPG use	326	0.069	0.113	0	0.923
Firewood use	326	0.741	0.241	0	1
Dirty fuel use	326	0.931	0.113	0.077	1
Forest zone	326	0.506	0.501	0	1
Savannah zone	326	0.331	0.471	0	1
Income[a]	163	6,553.44	8,340.5	-33,822.7	58,137.9
Treatment	326	0.304	0.461	0	1
Poor	326	0.317	0.239	0	0.957
Very poor	326	0.125	0.167	0	0.8
Refill Stations	326	2.776	4.017	0	23
Employed	326	0.624	0.117	0.305	0.980

[a] A few households recorded a negative net income due to losses they incurred from their non-farm enterprises.

The 2017 figures are equivalent to the 2013 figures in real terms. In our analysis, we defined "poor" as all households whose incomes are below the upper poverty line and "very poor" as all households whose incomes are below the lower poverty line.

Table 1 reports the summary statistics of the data arranged at the district level. It shows that dirty fuel use was considerably high during the two periods. LPG was used as primary cooking fuel by only 7% of households in a typical district, while close to 75% of households used firewood predominantly. Meanwhile, 93% of households used dirty fuels. Dirty fuel is a composite variable that captures the use of any type of dirty fuel, including firewood, charcoal, kerosene, and agricultural waste. The average proportion of poor households in a district was 31.7%, while the very poor made up 12.5% of a district on average. Approximately one-third of districts have benefitted from the RLPGPP implementation thus far. As shown in the last row, a district has 2.78 stations for refilling LPG cylinders on average. In other words, an average district has less than three refill stations. *Employed* measures the proportion of district residents who are employed and it averaged 62% over the period[6].

3.2. Methodology

This study uses matching techniques to mitigate the potential bias from the fact that the selection of treated districts might not be random. Based on pre-treatment characteristics, we match districts that benefitted from the RLPGPP (treated districts) to districts that did not benefit from the program (control districts). By matching districts with similar characteristics, any increase in LPG use in treated districts can be attributed to the implementation of the program. We use PSM to estimate the probability of a district being treated based on its pre-treatment characteristics [26]. The probability P(x) is equivalent to the propensity score:

$$P(x) = Pr(W = 1|x). \quad (1)$$

Eq. (1) gives the probability that a district is selected for treatment given its pre-treatment characteristics. An implicit assumption here is that for districts with the same propensity scores, the distribution of the outcome variable is the same for the treatment and control groups. The pre-treatment characteristics for matching[7] include the average household income in the district at the baseline as well as the district location based on the ecological zone.[8]

To reduce any possible bias that remains after matching, we employ the difference-in-differences (DID) estimator, which compares the change in outcome variables between treated and control districts. Through the DID estimation after matching, we reduce the potential bias associated with ordinary DID, which ignores different trends in outcome variables between treated and control groups. The DID estimator is modeled as in Eq. (2):

$$\Delta Yit = \beta Dit + \gamma Xit + \varepsilon it, \quad (2)$$

where ΔY_{it} denotes the change in outcome variables of district i at time t; D denotes the treatment indicator, which takes the value of 1 if a district benefitted under the RLPGPP in the post-treatment period and 0 otherwise; and X represents district characteristics.

4. Results and discussion

4.1. Spill-over impact of the RLPGPP on cooking fuel choice

First, we present and discuss the spillover impacts of the program on fuel choice. Table 2 reports the DID estimates after matching. In columns (1)–(5), the coefficients for the DID indicator are not statistically significant. The results suggest that the RLPGPP has not led to a significant increase in LPG use or a decrease in firewood use in beneficiary districts. However, there seems to be a decrease in dirty fuel use (column

[6] Overall, unemployment rate in Ghana was higher in 2016/2017 (8.4%) than in 2012/2013 (5.2%) owing to several factors including a protracted power crisis between 2012 and 2016.

[7] The results of balancing tests for PSM are reported in Appendix A.

[8] The Ghana Statistical Service classifies enumeration areas into ecological zones—coastal, forest, savannah, and the GAMA (Greater Accra Metropolitan Area).

Table 2
Effects on fuel choice.

	ΔLPG use		ΔFirewood use		ΔDirty fuel use	
	(1)	(2)	(3)	(4)	(5)	(6)
DID	0.007	0.010	-0.039	-0.044	-0.007	-0.016*
	(0.013)	(0.012)	(0.031)	(0.028)	(0.013)	(0.010)
Firewood use (Baseline)		0.231***		-0.389***		
		(0.044)		(0.108)		
Dirty fuel use (Baseline)						-0.624***
						(0.067)
Forest zone		-0.064***		0.163***		0.043***
		(0.021)		(0.050)		(0.015)
Savannah zone		-0.099***		0.226***		0.079***
		(0.023)		(0.056)		(0.015)
Constant	0.000	-0.123***	-0.020	0.139*	-0.001	0.549***
	(0.009)	(0.030)	(0.022)	(0.073)	(0.009)	(0.061)
Observations	98	98	98	98	98	98
R-squared	0.003	0.235	0.017	0.172	0.003	0.491

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Firewood use (Baseline) and Dirty fuel use (Baseline) in explanatory variables are measured for the pre-treatment period.

6) but its significance is quite weak, and this reduction did not lead to a significant increase in LPG use as replacement fuel.

Based on these results, we find no evidence that the RLPGPP has achieved its stated objectives on a nationwide scale after four years of implementation. Our finding is consistent with reports from some field surveys conducted in beneficiary districts. For example, Asante et al. [7] surveyed the Nkoranza North District and reported that more than half (58%) of beneficiaries had not refilled their cylinders once in the nine months after receiving them. Given that the size of cylinders in question is 6 kg, it is unlikely that households would still have gas in them after nine months if they were using them. The survey also found that all respondents continued to use fuelwood as their primary cooking fuel, despite benefiting from the program. The Ministry of Energy [22] reported that the frequency of LPG usage did not match that of cooking by beneficiary households in the Asante Akim North District. The implication is that fuelwood was still used for some cooking. Furthermore, the results implied that the beneficiaries had not made a total switch from dirty fuel. The survey further reported that only 22.9% of respondents confirmed that LPG had replaced the use of firewood in their households. These results from field surveys provide suggestive evidence for why our estimation shows no significant spill-over impact of the program on cooking fuel use at the district level. Furthermore, it is important to note that, for there to be a significant spillover effect of the program on fuel choice in the district through peer effects, there ought to be a critical mass of the district population benefitting from the program to create a strong enough influence on the other households in the district. However, we observe that the shares of population in the treated districts that benefitted from the program were very small. The ratio of cylinders distributed to the district population averaged 0.0149.[9] This paltry ratio could be partly responsible for the insignificant spillover effect of the program on fuel choice, as there might not have been strong enough peer influences to generate spillover effects.

Our results are in contrast with those of Calzada and Sanz [10] that the LPG program in Peru led to an increase in LPG adoption, particularly among lower-income groups. In Peru, vouchers are provided monthly, and hence, beneficiaries are assured of at least one filled cylinder every two months. The consistent support may be an essential factor contributing to the high adoption of LPG for beneficiaries of the program as opposed to the Ghanaian case, wherein beneficiaries receive a filled cylinder only once and must bear the financial burden of refilling by themselves. Our findings also contrast those of Adjei-Mantey et al. [4] which found a positive impact of the program in Ghana. That study used a sample from districts in the Greater Accra Region, where the nation's capital is located. Districts there may have benefitted from other factors including improved service infrastructure due to their proximity to the capital leading to positive impacts in those districts. Indeed, Adjei-Mantey and Takeuchi [2,3] show that residents in districts with more refill stations and shorter distances to refill cylinders are more likely to switch to LPG use. Our results are also contrary to the findings of two previous studies [15,18]. In the case of South Africa, Kimemia and Annegarn [18] found that following the program intervention, LPG replaced the use of wood or paraffin. The study observed that LPG was perceived to be cheaper than electricity, while the reliability and reduced cooking time compared to combustible fuels were considered benefits. In addition, the regulation to control the maximum price of LPG, a feature missing in Ghana's policy, keeps the fuel affordable and contributes to the success of the program in South Africa. Similar to Kimemia and Annegarn [18], Imelda [15] found an increase in the number of households that use LPG after the intervention of a fuel conversion program in Indonesia. The main feature of the intervention in Indonesia was the removal of subsidies on kerosene and the introduction of subsidies on LPG. The subsidies were useful in promoting a mass switch to LPG. The result is also supported by studies of Gould and Urpelainen [13] and Troncoso and Da Silva [28]. on the adoption of LPG and that of Bensch, Grimm, and Peters [8] on the uptake of improved cookstoves.

4.2. Impact of the RLPGPP on poverty and implications for wellbeing

Although the objective of the RLPGPP is to create a shift in primary cooking fuels, it may have unintended impacts through the associated change brought to the beneficiary community. Thus, we estimate the likely impact of the program on poverty reduction. Columns (2) and (5) of Table 3 report the estimation results. The results show a statistically significant association between poverty and treatment, as the percentage of households in the district that live in poverty declines by 12.8%. Moreover, the percentage of people who live in extreme poverty is reduced by 10.2 % in treated districts. Our findings are in line with, for example, Williams et al. [29] who found that clean cooking fuel interventions reduce poverty and improve welfare. The significant poverty reduction cannot be attributed to reduced firewood use, as postulated in our hypothetical framework, because the earlier results show no significant decrease in firewood use.

Therefore, we explore the likely channels through which the program implementation could have yielded a significant association with poverty reduction. As a potential channel, we investigate the impact of refill stations. According to the National Petroleum Authority of Ghana—the regulatory agency with responsibility for LPG—the number of LPG refill stations across the country increased from 394 in 2012 to 639 in 2017, representing a 62% increase over the course of the RLPGPP implementation. To check whether the program implementation led to a significant increase in infrastructure, we use the number of refill stations as an outcome variable. The results are shown in column (1) of Table 3. It shows a positive and significant effect of treatment on the number of refill stations. This confirms that there were significantly more refill stations constructed and opened in treated districts than in control districts. As there is a sufficiently high number of cylinders in circulation within a treated district, LPG marketing companies are motivated to set up refill stations in the beneficiary districts to take advantage of the market. Employment opportunities become available for residents during the construction and operation of the stations. In addition, the establishment of a station enhances the infrastructure of the area. It has the potential to stimulate economic activities and provide a larger market for rural farm produce. Therefore, we include refill stations in the poverty models to test for its effect on poverty reduction.

Models (3), (4), (6) and (7) in Table 3 report the impact of the number of refill stations on poverty reduction. We include the change in the

[9] This ratio was calculated by dividing the number of cylinders distributed by the population in each district.

Table 3
Effects on number of refill stations and poverty reduction.

	ΔRefill Stations	ΔPoor			ΔVery poor		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DID	0.531*	-0.128**	-0.121**	-0.112**	-0.102**	-0.097**	-0.090**
	(0.276)	(0.057)	(0.054)	(0.054)	(0.041)	(0.040)	(0.040)
ΔRefill Stations			-0.058***	-0.058***		-0.034**	-0.033**
			(0.018)	(0.018)		(0.014)	(0.013)
Δ Employed				0.338*			0.292**
				(0.195)			(0.143)
Constant	0.490**	0.161***	0.213***	0.230***	0.118***	0.148***	0.163***
	(0.195)	(0.040)	(0.042)	(0.043)	(0.029)	(0.031)	(0.031)
Observations	98	98	98	98	98	98	98
R-squared	0.037	0.050	0.140	0.166	0.060	0.117	0.154

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 "Poor" refers to the percentage of households below the upper poverty line—those officially classified as "poor" and "very poor." "Very poor" refers to the proportion of households in the district that are below the lower poverty line—only those classified as "very poor" in the official classification.

Appendix A1
Balancing test results of estimations of matching for fuel choice and poverty.

		Mean					
Variable		Treated	Control	% bias	% reduction bias	t	p>t
Ecological	Unmatched	2.327	2.124	29.4		1.78	0.077
zone	Matched	2.327	2.327	0	100	-0.00	1.000
Income	Unmatched	8174.3	7294.6	8.4		0.46	0.643
	Matched	8174.3	8239.5	-0.6	92.6	-0.04	0.969

number of LPG refill stations (ΔRefill Stations) between the baseline and end line as an explanatory variable in these regressions. Consequently, we find that an increase in refill stations significantly correlates with a reduction in the proportion of households living in poverty (extreme poverty) by 5.8% (3.3%). In addition to the construction phase of the station, which gives employment opportunities to residents, the operation of the refill stations leads to the creation of direct and indirect jobs for residents. This is because people become employed to provide direct services at the refill stations, and others provide auxiliary services for the effective operation of the stations. Furthermore, the refill stations are likely to keep operating for a reasonable period after their establishment. Therefore, it is possible that economic activities are promoted by the establishment of refill stations and could be partly linked to poverty reduction in treated districts. The provision of jobs gives people income which consequently helps to enhance the wellbeing of residents in treated districts. The results confirm the findings of Kimemia and Annegarn [18], who found that in South Africa, jobs and economic opportunities became available in beneficiary areas, and consequently, led to a reduction in poverty.

5. Conclusions and policy implications

Although the RLPGPP is a commendable program in principle, the findings from this study suggest that it has not yielded a significant spillover impact on cooking energy choices in rural households in Ghana that can be observed at the district level. The program has likely not substantially increased LPG use among households, nor has it decreased firewood use. However, our empirical results show that the program possibly has contributed to poverty alleviation in the treated districts. Having matched treated and control districts, we find that the percentage of poor and extremely poor households decreased over the period of the program implementation in those districts. Furthermore, we find that the construction of new refill stations is a possible channel for enhanced economic well-being. A limitation of the study is that following the matching of treated to control districts, unmatched districts were dropped thus rendering the sample size limited compared to the geographical coverage of the program.

This limitation notwithstanding, the findings of this study suggest a necessary improvement of the implementation strategy of the program for household energy transition. The implementing agency should design a strategy for the program based on its original aim: to encourage a switch to LPG as the primary cooking fuel. When implemented in isolation, it would be difficult for the RLPGPP to have a meaningful impact regarding its primary objective of increasing LPG use for cooking. However, if implemented in conjunction with adequate infrastructure and refill plans in place, it could yield significant impacts on fuel switching and poverty alleviation.

Data availability

The data used for this study is publicly available at www.statsghana.gov.gh

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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