



Essays on household cooking energy in Ghana

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博 士 論 文

令和 3 年 6 月

神戸大学大学院経済学研究科

経済学専攻

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(ガーナにおける家庭の調理燃料に関する実証研究)

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ABSTRACT

Energy is an indispensable factor in the development agenda of every country. It is even more critical for developing countries in the quest for the path to sustainable development. This is true not only for industrial and commercial activities but also for household energy use as well. Previous studies have highlighted increasing exposures to household air pollution resulting from dirty fuel usage or poor energy choices in general. Recent literature also suggests the importance of household energy choices to accelerate the achievement of the sustainable development goals. This thesis is a compilation of several essays on household energy use for one such developing country – Ghana.

This thesis aims to contribute to the literature on household cooking energy by four empirical studies in Ghana. First, we examine the negative health consequences of dirty fuel use at the household level. Secondly, we investigate how a behavioral factor affects household cooking fuel choices. Third, we examine the spillover effects of government interventions that promote clean household cooking fuels on fuel choice and poverty reduction. Lastly, we investigate the direct impacts of such interventions on household usage of cooking fuel, explore households' stated preference for LPG delivery, and examine a supply side factor that might influence household cooking fuel choices. Using data from both official nationwide statistical surveys and the author's own field survey, this thesis employs several econometric methods to arrive at its results and conclusions. Instrumental variables, matching, and matching with difference in differences are among several techniques adopted to investigate the relationship between response variables and explanatory variables.

Chapter two examines the effect of exposure to household air pollution on child health and finds that there are latent effects of dirty fuel use on child health in Ghana. By employing the two-stage residual inclusion technique to account for potential endogeneity, it was observed that children exposed to household air pollution *in utero*, i.e., those born in districts with high dirty fuel use tend to become shorter on average after birth compared to children born in the districts with lower dirty fuel use.

Chapter three investigates the role of behavioral factors in clean cooking fuel choice and finds that risk averse households are less likely to adopt LPG as their primary cooking fuel due to the

risks associated with LPG use in Ghana. However, policy to make LPG more available and easily accessible will be effective in mitigating the negative effects of risk aversion on LPG adoption.

In chapter four, we evaluate the Rural LPG Promotion Program, a government intervention to aid the transition to cleaner fuel. Matching with difference in differences techniques were used to analyze the data. We found that while the program had no evidence to support its effectiveness in yielding significant spill-over effects on fuel choices at the district level, there was evidence to support its significant effect in reducing poverty in treated districts potentially through the increase in refill stations in beneficiary districts.

We find in chapter five that at the household level, however, there is evidence of significant positive effects of the program on LPG adoption and regularity of use while distance to refill stations was identified as a key obstruction in the adoption and use of LPG. In addition, we find that refill station features that reduce time and money costs of commuting to refill stations influence LPG use positively. Significant heterogeneities were observed in treatment effects leading to the conclusion that different sub-groups of the population, particularly agricultural workers may require different forms of treatment in order to use LPG more.

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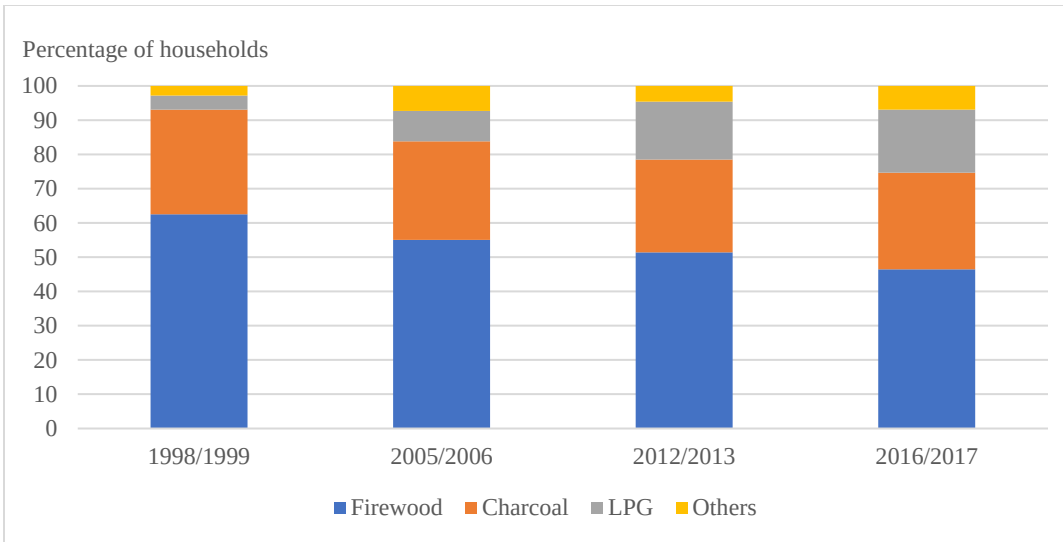
CHAPTER ONE

Introduction

1.1 Background

Energy is an indispensable factor in prosecuting the development agenda of any country. With recent emphasis on sustainable development, the types of energy adopted and used is becoming even more critical. This holds true not only for the industrial and commercial sectors but also for the household sector. Households typically demand energy for activities including cooking and heating. More than three billion people across the world use dirty and traditional fuels such as biomass fuels (Bryden et al., 2015). Particularly in developing countries, up to 95% of the population use such fuels (Gordon et al., 2014). The use of these fuels has implications for both users' health and the environment. In the quest for the path of sustainable development, such countries have to address the issues relating to household fuel use.

Ghana is one of such developing countries where household cooking energy is a matter of concern. Statistics from the most recent national survey (the Ghana Living Standards Survey VII: GLSS 7) suggest that about half of households use firewood as their primary cooking fuel. This is followed by charcoal, also generally dirty but less polluting than firewood. Cleaner household cooking fuel is mainly the Liquefied Petroleum Gas (LPG) which is used by less than a fifth of households. It is important to note that use of multiple cooking fuels, generally referred to in the literature as fuel stacking is not uncommon in Ghana. However, it is equally typical for households to designate a specific fuel as the household's primary fuel which the household normally uses for cooking everyday meals. In this thesis, primary fuel refers to that. Other fuels are used in the household as contingency fuels or for cooking special meals occasionally. Figure 1.1 shows that LPG use as primary fuel increased only marginally over the past two decades and firewood use is slightly declining.



Source: GLSS 4, 5, 6, 7. N = 5,998 (GLSS 4 [98/99]); 8,687 (GLSS 5 [05/06]); 16,737 (GLSS 6 [12/13]); 14,009 (GLSS 7 [16/17])

Figure 1.1. Trends in primary cooking fuel choices over time

Using dirty fuels exposes household members particularly women and children to household air pollution with its associated health risks. Demands for firewood and charcoal also have an environmental impact through forest degradation. These concerns have prompted policy makers to implement interventions to promote the use of cleaner cooking fuels particularly among poor communities. Many developing countries including Ghana, Peru, India, Ecuador, and South Africa have historically implemented various policies to aid the transition to cleaner cooking fuel use. Despite these interventions, however, many households in developing worlds persist in using traditional cooking fuels.

1.2 Objectives

While a growing body of studies examine various topics relating to household energy, there remain important questions to be answered and key areas yet to be investigated. This thesis aims to explore the pertinent issues surrounding household cooking fuels in Ghana in separate essays. First, the thesis examines the effects of exposure to household air pollution (HAP), which results from the use of firewood and charcoal on child health. Empirical evidence on latent health effects such as child stunting, resulting from HAP exposures are scarce when compared with the

abundance of studies on more manifest effects such as respiratory symptoms or carcinogenic effects. The examination of the relationship between child stunting and exposure to HAP is carried out in chapter 2 of this thesis and it enriches the literature on the effects of dirty fuel usage by households and the resulting exposures to household air pollution. The thesis proceeds to then explore the role of behavioral factors, particularly risk aversion, on clean cooking fuel choice in chapter 3. Given the persistent use of cooking fuels despite interventions and what is known from previous literature, it is imperative to conduct more research on the cognitive factors that account for fuel choices in order to be able to address cooking fuel choice concerns. Empirical examination of risk aversion's role in fuel choices remain scant and this thesis fills a research gap in this regard. Thirdly, this thesis investigates the impact of a clean cooking intervention in Ghana. As previously mentioned, Ghana has implemented an active LPG promotion intervention, the Rural LPG Promotion Program (RLPGPP). This thesis investigates the intended and unintended spill-over effects of the program in beneficiary districts using official statistical surveys in chapter four, as well as more direct impacts using data obtained from a field survey in two beneficiary districts in chapter 5.

This thesis answers key questions including: does exposing expectant mothers to household air pollution from dirty fuel use have any adverse effect on the height of children after birth? Does risk aversion affect the choice of clean fuel in Ghana? If so, how can policy mitigate the effect of this behavioral trait? Has the RLPGPP, a government intervention for the clean fuel transition, yielded significant primary and secondary spill-over impacts in beneficiary districts? Has the RLPGPP increased LPG use among beneficiary households and if so, which categories of households respond best to such interventions? How does the distance to refill stations and additional services provided at the stations affect the LPG use? How much are households' willingness to pay for an improved LPG distribution? The answers to these questions provide significant contribution to the literature as discussed under each chapter.

1.3 Summary of results

The novel and key findings of this thesis can be summarized as the following. Firstly, *in utero* exposure to household air pollution, resulting from dirty fuel use during pregnancy leads to lower heights in children after birth. Secondly, risk aversion negatively affects the choice of LPG as

primary cooking fuel after controlling for factors such as income and education. Risk averse households are less likely to opt for LPG but this behavioral tendency can be mitigated by ensuring ease of availability of LPG in residential locations. Thirdly, while there is not much evidence to show a positive spill-over effect of the RLPGPP on fuel choice among beneficiary districts, the program might reduce the poverty in beneficiary districts potentially through the opportunities brought about by the increase in LPG refill stations. At the household level, however, there is an evidence of the program's positive impact on LPG choice as primary fuel with heterogeneous effects observed among different sub-groups of the population. Furthermore, distance to the refill station has strong negative links with the choice of LPG as primary cooking fuel while there is significant stated preference for a more convenient model of LPG delivery. The implications of each of these findings for policy making and promotion of clean cooking fuel are discussed under each chapter.

References

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Gordon, Stephen B., Nigel G. Bruce, Jonathan Grigg, Patricia L. Hibberd, Om P. Kurmi, King-bong Hubert Lam, Kevin Mortimer, et al. (2014) Respiratory risks from household air pollution in low and middle income countries. *Lancet Respiratory Medicine* 2:10, 823-60.

CHAPTER TWO

The Effect of In Utero Exposure to Household Air Pollution on Child Health: Evidence from Ghana

Abstract

This chapter examines the impact of in utero exposure to household air pollution on child health. By using a pseudo panel data compiled from three rounds of two separate household datasets in Ghana, we investigate the impacts of dirty fuel use on child stunting at the district level. The results indicate that exposure to household air pollution in utero causes stunting in children after birth. We found that children born in the districts using firewood or charcoal as a main cooking fuel are shorter on average after birth. The estimated impacts are sizable: for example, by switching cooking fuel from dirty fuels to LPG, the average height for age Z score in the sample would increase from -1.269 to -0.43 . The findings imply that policy to enhance clean cooking fuel use will help reduce child stunting in developing countries. An increase in clean cooking fuel usage and a reduction in child stunting are both necessary to support the success of the SDGs.

Keywords

Household air pollution; cooking fuel; Ghana; height for age; stunting

2.1. Introduction

More than three billion people in the world use traditional biomass fuels,¹ e.g. wood, agricultural waste, charcoal, and animal dung, for household cooking and heating purposes (Bryden et al., 2015). The combustion of such fuels leads to household air pollution (HAP), that increase the risk of serious health consequences (Lim et al., 2013).² World Health Organization (2018) estimated that about 3.8 million deaths occur annually as a result of exposure to indoor air pollution. Midouhas et al. (2018) indicated that exposures to poor indoor air quality could lead to detrimental cognitive effects in young children. It is also widely documented that coal and biomass combustion releases various chemical pollutants including carcinogens (International Agency for Research on Cancer, 2006; Sapkota et al., 2013). Each of these concerns highlight the need to investigate causal links between the cooking fuel choices and their health consequences.

A significant number of households use traditional biomass fuels for cooking in developing countries. Indeed, up to 95% of the population in poor countries use such fuels (Gordon et al., 2014). Estimates show that 10% of the mortality in low- and middle-income countries can be attributed to HAP as opposed to 0.2% in high-income countries.³ This study focuses on Ghana where over 72% of the households use wood or charcoal as their main cooking fuel. In urban Ghana, over 43% of the households use charcoal as their main cooking fuel, while 79% of the rural households use wood as their main cooking fuel. Hansen et al. (2009) notes that per capita consumption of charcoal in Ghana is the highest among the West African countries. Moreover, Adusah-Poku and Takeuchi (2019) found that cooking is the most serious dimension regarding energy poverty in Ghana thus, confirming that a larger share of households resort to dirty cooking fuels.

The objective of this chapter is to examine the impact of HAP exposure in utero on child health in Ghana. Epidemiological literature has suggested that events during the period of pregnancy can affect the infant in a way that are apparent at birth or leads to later disease (Almond and Currie, 2011). Econometric studies have found negative consequences of early life exposure to air pollution on child health (Currie et al., 2013; Jayachandran, 2008) while others found improvement in air quality positively associated with improvement in child health (Gauderman et al., 2015).

¹ The terms traditional biomass fuels, solid fuels, and dirty fuels are used interchangeably in this study.

² The terms household air pollution and indoor air pollution are used interchangeably in this study.

³ WHO Global Health Observatory Data. https://www.who.int/gho/phe/indoor_air_pollution/burden_text/en/

Others have underscored the importance of controlling air pollution in developing human capital (Zivin and Neidell, 2013). However, the causal relationship between in utero HAP exposure and child stunting has not been well investigated.

Stunting is an indicator of impaired growth and development in children. WHO defines child stunting as having a height for age more than two standard deviations below the WHO Child Growth Standards median. About 162 million children in the world are stunted, and the figure will remain 127 million by 2025 if the current trend is unchanged (WHO, 2014). Among the effects of child stunting, reduced cognitive development has serious implications for economic disadvantages later in life. Stunting is also associated with increased risk for degenerative diseases such as diabetes (UNICEF, 2013). One of the sustainable development goals (SDGs) is to end all forms of malnutrition by 2030, including achieving by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age.

This chapter estimates the effect of cooking fuel use on child stunting, which has received less attention in the literature. The first contribution is that we focus on child stunting as the impact of HAP. Existing studies on health impact of HAP have focused on conditions such as respiratory infections and carcinogenic effects (Upadhyay et al., 2015) or birth weight and preterm birth (Backes et al., 2013). A few studies looking at the child stunting did not trace back to in utero effects (Mishra and Retherford, 2007) or focused on outdoor air pollution (Goyal and Canning, 2018). In short, the impacts on child stunting emanating from in utero exposure to HAP have been under-investigated. Empirical evidence obtained in this study provides helpful insight to understand the policy impact to reduce child stunting.

The second contribution of the study in this chapter is our methodology that combines different rounds of cross-sectional household data to create a panel dataset at the district level. This allows us to examine the impacts in larger geographical scope for a considerably long period. Furthermore, the study combines two different datasets (the Ghana Demographic and Health Surveys (GDHS) and the Ghana Living Standards Surveys (GLSS)) that span a period of 16 years. Most previous studies rely on cross-sectional data, one type of data, or data that cover a shorter time period (Jayachandran, 2008; Imelda, 2018). Our study is unique in how we combine two data types over the 16-year period to estimate the causal impact.

There are still few studies in the area of indoor air pollution in Ghana. Although Armah et al. (2013) touch on areas such as the environmental degradation of fuelwood use and socio-environmental determinants of exposure to HAP, they do not evaluate the detailed impacts of exposure to HAP on a variable such as child health. In addition, their study does not use data that cover the entire country. In that respect, our study makes an important contribution to the field.

The rest of this chapter is organized as follows. In Section 2.2, we review the status of cooking fuel use in Ghana. Section 2.3 provides a literature review. Section 2.4 describes our data and empirical methodology. Section 2.5 presents the results of the empirical analysis and a discussion. Section 2.6 concludes the chapter.

2.2. Household cooking fuel usage in Ghana

Firewood, charcoal, and liquified petroleum gas (LPG) are the main fuel types used by households in Ghana. A few households use other fuels such as crop residue, kerosene, shrubs/grass, and electricity. Although the use of firewood has declined from 62.5% of the households in 1998 to 51.4% of the households in 2013, it is still the most common cooking fuel followed by charcoal, which has maintained its share of household usage at approximately 30% over this period. While the use of LPG has increased from 4.1% in 1998 to 16.9% in 2013, the proportion as the primary fuel remains low.

The status of cooking fuel usage in rural and urban areas is as follows: Around 51% of the national households use firewood, while about 27% use charcoal. That brings the total proportion of households using dirty fuels to about 78% with only 17% using LPG. In urban areas, 52.5% of households in the Greater Accra Metropolitan Area comprising municipalities within Tema and Accra, the capital city, use LPG as opposed to only 27% usage in other urban areas. By contrast, more than three-quarters (79%) of rural households use firewood with only 4.2% using LPG.

The statistics provided show that dirty fuel usage is generally high across the country. The implication is that households are exposing themselves to HAP either knowingly or unknowingly. Whether they are fully aware of the potential health risks of such exposure should be a matter of concern both among researchers and policymakers. In this context, our empirical analysis cast light on the potential health risks for households in the cooking space. In addition, the research may

point to areas for growth in the economy while meeting environmental targets, as Ghana aims to reach a 50% household LPG access by 2020 (Energy Commission, 2012).

2.3. Literature Review

Several studies have investigated the impact of HAP on human health. Imelda (2018) studied the causal impact of a fuel-switching program on infant mortality in Indonesia using the country's Demographic and Health Survey. By employing a quasi-experimental approach, the study found that switching to cleaner fuel was associated with a reduction in infant mortality by 4 per 10,000 live births representing a 1.1% drop in the infant mortality rate. The study concluded that the fuel-switching program reduced infant deaths by 600 annually; thus, an estimated 7,000 deaths per year could be avoided in the developing world.

Barron and Torero (2017) conducted a study on household electrification and indoor air pollution in El Salvador. In their study, the government covered a proportion of the installation costs of electricity while the households had to cover the costs of wiring their homes and paying for safety certificates to connect to the grid. Following sample households over a five-year time period, the authors estimated the impact of connecting to the national electricity grid on indoor air pollution and reducing their usage of kerosene lamps and candles at night. Two years following the expansion of electricity in the area under study, they observed that the concentration of PM_{2.5} measured overnight was about 66% lower for households randomly selected for receiving vouchers to connect to the electricity grid. Subsequently, the treated group recorded 4 to 8% reduction in child acute respiratory infections; ascribing part of this reduction to reduced kerosene usage as a result of electrification. The studies of Imelda (2018) and Barron and Torero (2017) incidentally measure the impact of reducing kerosene usage on child health. While the former focuses on mortality, the latter focuses on acute respiratory infection (ARI). They both conclude that the reduction in kerosene usage is associated with a significant improvement in the child health variables they measure. In addition, Barron and Torero (2017) go further to affirm the effects of improvement in air quality for households in their treatment group; positing this as responsible for the reduction in child ARI in their study area.

Upadhyay et al. (2015) studied the impact of indoor air pollution on respiratory illness of children in India. Using panel data for two time periods, they estimated the odds of children contracting life-threatening respiratory illness in households that used solid fuels. They discovered that children in households that used solid fuels in both time periods were more likely to suffer at least one episode of life-threatening respiratory illness than children from households that used solid fuels in only one time period. They also found that the risk of suffering from the health condition was 1.78 times higher for children in households using solid fuels than for children in households using other fuels.

In the context of ambient air quality, several studies have focused on the impacts of the early life exposures on child health. Jayachandran (2008) investigated the effects of forest fires in Indonesia on fetal and infant mortality. Due to thick smoke generated as a result of the fires, air quality suffered greatly and the study found that the air pollution led to a reduction in the number of children who survived beyond age three. They found fetuses who were exposed in their last trimester in utero to have suffered the most damage from the high air pollution at the time. In total, the author links 15,600 deaths of fetuses, infants and children to the poor air quality resulting from the fires. Goyal and Canning (2018) also address the issue of ambient air quality exposure in utero and its child stunting risk potential in Bangladesh. They found that children within high exposure quartiles were found to have a risk of stunting of 1.13 times higher than children within the lowest quartile of exposure. Although the study of Goyal and Canning (2018) focuses on ambient air quality, the results clearly suggest that exposure to air pollution in utero has negative implications for child health. As mentioned in Section 1, our study differs from the above studies in that we examine the effects of HAP on child stunting. While households' choice could directly influence their exposure to HAP, same cannot be said of outdoor air pollution and hence this study gives households the evidence to make better decisions about their fuel choices as far as it lies in their capacity to do so.

2.4. Data and Empirical Methodology

2.4.1 Data

Our study employs the nationally representative Ghana Demographic and Health Surveys (GDHS) IV, V, and VI (GSS & The DHS Program) collected in 2003, 2008, and 2014, respectively, and the Ghana Living Standards Surveys (GLSS) IV, V, and VI (GSS) collected in 1998/99, 2005/06, and 2012/13, respectively. Each round of the data covers thousands of households sampled across the entire country. Data for the variables *Height for age* for children under five, *Mother's height for age* and *Mother's schooling* are from the DHS data while other variables are from the GLSS. These datasets represent the most comprehensive data available at the household level in Ghana regarding economic, health, and demographic characteristics. From these datasets, we compile average statistics at the district level. For a specific age range, we can see the children's height for age in the district at a particular point in time and relate it to the exposure to HAP in the district at the time these children were in utero. This allows us to estimate the effects of HAP on children exposed while in utero on height for age at the time of the survey. (For example, the height for age of children who are aged between four and five years old in 2003 can be linked to exposure to HAP in 1998/99 when these children were in utero). Notably, the households interviewed were different in each of these surveys and, therefore, we built a pseudo panel data at the district level to investigate the relationship between the cooking fuel choice and the health outcome.

Although the DHS data did not contain household locations in terms of administrative districts, we were able to obtain geographic data in the form of GPS coordinates. Using a spatial analysis tool, *QGIS*, we find the geographical location of households, construct district averages for the variables of interest, and build a panel data across all districts over time. We used a similar approach with the GLSS data. Because districts have been coded differently between the two datasets, we referred to the codebook supplied by the Ghana Statistical Service (GSS) to assign an identity code to each district to align with the findings from the DHS data. Regarding newly created districts over the period, we relied on the legislation from the parliament of Ghana that created new districts to determine their parent districts and matched new districts with them to be able to build a consistent dataset for all the rounds of data. Subsequently, we built a panel of all districts

over time. There are 110 districts in all⁴ but we end up with an imperfect panel because of a few observations with missing data for some variables in at least one of the time periods. Finally, we merged the two panel data created from the DHS and the GLSS to form an entire dataset.

2.4.2 Empirical Methodology

Variables relating to the exposure to HAP are potentially endogenous. It could arise from the fact that households that use cleaner fuels may be those that pay greater attention to better health and thus, may take other unobservable measures to improve their children's health. To address this, we employed an instrumental variable approach. We used a non-linear model with fractional regressors and, following the approach of Terza et al. (2008) to address endogeneity, we employed the two stage residual inclusion (2SRI) strategy. This strategy is markedly different from the more popular two stage least squares (2SLS) since the 2SLS generates inconsistent estimators in the presence of non-linearity.

At the first stage of the 2SRI, we regressed exposure to HAP through cooking fuel type on the instrumental variable and other explanatory variables with following model:

$$Y_{it} = \alpha + \beta X_{it} + \gamma W_{it} + \varepsilon_{it} \quad (2.1)$$

where Y is the type of cooking fuel used, X is a vector of observed household characteristics and W is the availability of LPG for purchase by households, which serves as an instrument in this model. Subscripts i and t denote district i at time t and ε is the error term. After estimating (1), residuals from this regression, r , are duly generated.

At the second stage of the 2SRI, we regressed child health on independent variables of interest and the residual from the first stage of the regression.

$$Z_{it} = \delta + \eta Y_{it} + \theta X_{it} + \lambda r_{it} + \mu_{it} \quad (2.2)$$

⁴ The 110 districts do not imply the exclusion of any district. New districts created within the study period are included in their parent districts from which they were carved.

where Z is a child's height for age Z-score and r is the residual predicted from the first stage.

2.5. Results and Discussion

2.5.1 Estimation Results

Table 2.1 presents the descriptive statistics of the variables used in our analysis. The health outcome variable is height for age and the explanatory variables include indicators relating to cooking fuel use (firewood or dirty fuel), number of years of schooling of mothers, height for age of mothers and income, and availability of LPG as an instrument variable.

The study uses the height for age standard deviation according to WHO reported in the DHS data. The WHO considers a child stunted if his/her height for age Z score falls less than two standard deviations from the median of the benchmark population's height for age. Based on this definition of stunting, a positive Z score deviation from the median is preferable to a negative one. The Z score is calculated as follows:

$$\text{height for age Z score} = \frac{\text{observed value} - \text{median value of reference population}}{\text{standard deviation of reference population}}.$$

The mean value of height for age Z score was -1.269 . This means an average child in our sample is not stunted but has a height for age which is 0.731 standard deviations away from being stunted.

The variable *Firewood* in Table 2.1 refers to the share of households in a district that use firewood as their primary cooking fuel. On average, 67.7% of households in the sample use firewood and 93.6% use dirty fuel. The variable *Dirty fuel* refers to households that use firewood, charcoal, kerosene or agricultural waste. *Mother's height for age* is to control for genetic factors in a child's height for age while *Mother's schooling* is used to control for the role of parental education in child health. *Income* sums up the total net income received by households from all sources including primary employment, farm and non-farm income, and rent income. Finally, *Gas availability* is an indicator of how households found LPG available whenever they tried to purchase it.

Table 2.1: Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Height for age	319	-1.269	0.805	-3.18	1.34
Firewood	321	0.677	0.249	0	1
Dirty fuels	321	0.936	0.101	0.431	1
Mother's height for age	319	-0.785	0.473	-3.34	0.92
Income (in Gh¢ '000)	321	5.140	7.262	0.053	38.119
Mother's schooling	321	5.046	2.994	0	20.357
Gas availability	248	0.659	0.355	0	1

Note: The average exchange rate was \$1: Gh¢ 2.07 for 2013, the latest round of the GLSS data used for this study.

Table 2.2 presents the results from the first stage regression. We observe that our instrument, *Gas availability*, can account for the potential endogeneity of the cooking fuel variable. A negative and statistically significant coefficient indicates that the household's choice of fuel is influenced by the availability of LPG in their communities whenever they tried to purchase it. As the availability of LPG increases, usage of firewood and dirty fuels in a typical household is reduced.

Table 2.2: First stage of 2SRI regression estimation results

	(1) Firewood	(2) Dirty fuels
Charcoal	-1.066*** (0.030)	
Location (urban=1)	-0.097*** (0.023)	-0.109*** (0.022)
Income	-0.004** (0.002)	-0.006*** (0.002)
Gas availability	-0.042*** (0.014)	-0.049*** (0.013)
Constant	1.076*** (0.017)	1.082*** (0.016)
Time fixed effects	Yes	Yes
Observations	241	241
Number of districts	110	110

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The second stage of the analysis includes the residual predicted from the first stage regression as a regressor in determining the impact of HAP in utero on children's height for age. The results are reported in Table 2.3.

Table 2.3: Second stage of 2SRI regression estimation results

Dependent Variable: Height for age Z score	(1)	(2)
Firewood	−0.565*** (0.212)	
Residual (firewood)	−0.089 (0.493)	
Dirty fuels		−1.769*** (0.586)
Residual (dirty)		0.742 (0.757)
Constant	−1.163*** (0.184)	0.205 (0.569)
Time fixed effects	Yes	Yes
Observations	239	239
Number of districts	109	109

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Estimation results in Table 2.3 show that the residual from the first stage regression is not significant. This implies that endogeneity is not a problem in our model and, hence, adding the residuals in our estimations as we have them in Table 2.3 overestimates the impacts of in utero HAP on child health. This may be because the source of endogeneity is suspected to be at the household level and by constructing district level averages the type of cooking fuel used can be treated as exogenous (Koolwal and van de Walle, 2013; Nauges and Strand, 2017). Therefore, we run a model that does not account for endogeneity with the results presented in Table 2.4.

Table 2.4: Results without residual regression

Dependent Variable: Height for age Z score	(1)	(2)	(3)	(4)	(5)	(6)
Firewood	-0.456*** (0.152)	-0.447*** (0.151)	-0.325** (0.149)			
Dirty fuels				-1.238*** (0.291)	-1.287*** (0.299)	-0.899*** (0.352)
Income		0.007 (0.008)	0.005 (0.008)		0.005 (0.008)	0.004 (0.008)
Mother's height for age		0.352*** (0.088)	0.366*** (0.085)		0.359*** (0.086)	0.370*** (0.083)
Mother's schooling			0.035*** (0.013)			0.033*** (0.014)
Constant	-1.309*** (0.141)	-1.055*** (0.154)	-1.287*** (0.164)	-0.440 (0.298)	-0.125 (0.311)	-0.639** (0.386)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	310	310	310	310	310	310
Number of districts	110	110	110	110	110	110

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

We see a statistically significant and negative relationship between firewood use during pregnancy and the height for age of children. A similar observation is found for dirty fuel use and height for age of children in a district. A unit increase in average dirty fuel use within a district reduces the height for age standard deviation of children by 0.899 from the median of the WHO Child Growth Standards. For firewood use, this increase leads to a drop of 0.325 in the height for age standard deviation. For our particular sample where the average district has a height for age Z score of -1.269 with 67.7% using firewood and 93.6% using dirty fuels, the implications of the results can be summarized as follows. If a district that uses firewood switches their cooking fuel to charcoal or LPG, the average height for age Z score in the sample would increase to -1.049, which is an improved height for age compared to the mean height for age Z score. In the case of a district that uses dirty fuel, a switch to LPG would lead to the height for age Z score increasing to

-0.43⁵, a further improved height for age, and farther away from the stunting threshold of -2. Figure 2.1 provides a visual expression of these findings.

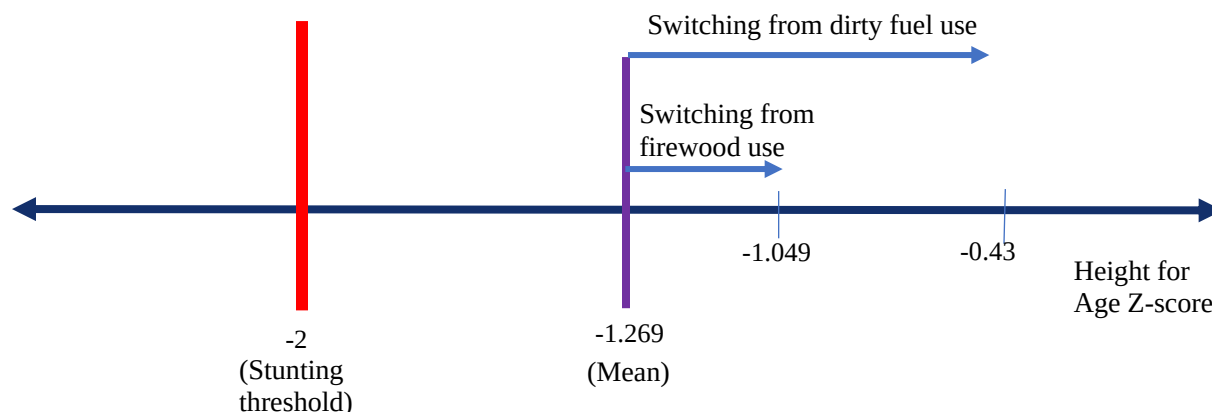


Figure 2.1: Implication of coefficient estimates

In other words, children who would have less than the average height for age, stand a greater risk with each increase in firewood usage while in utero under *ceteris paribus* assumptions. The dirty fuel usage is even worse, for it exposes a child to higher risks of stunting. Because alternative choices to firewood are charcoal and LPG, the impact of switching from firewood to other fuels is smaller compared to the impact of switching from dirty fuels to LPG. Our findings agree with Kurata et al. (2020) and Goyal and Canning (2018) who observed that exposure to outdoor air pollution in utero also increases the risk of stunting in children in Bangladesh. Shortening of telomeres might be a potential mechanism for the association between *in utero* air pollution and stunting. Exposure to air pollution *in utero* potentially leads to effects which include reduction in telomere length through the activation of reactive oxygen which consequently contributes to lower heights in later life (Sinharoy et al., 2020; Iodice et al., 2018). We also found that the years of mothers' schooling have a positive relationship with the height for age of their children. Empirical evidence has found that mothers' education tends to have an impact on their children's health (Chen and Li, 2009; Chou et al., 2010). Educated mothers might be able to better utilize

⁵ The switch from firewood is only possible for the 67.7% of districts that use firewood as their primary fuel. Thus, the expected response from a switch from firewood is $0.677 \times 0.325 = 0.22$. The mean height for age Z score of the sample would thus be enhanced by 0.22. Similarly, the switch from dirty fuel is only possible for the 93.6% of districts that use dirty fuel. Hence the expected response from such a switch is $0.936 \times 0.899 = 0.84$.

information around them to enhance the health of their children. In our example, mothers who have been in school longer might know the effects of HAP and to avoid exposure during pregnancy. Accordingly, they might visit health facilities during pregnancy and obtain the appropriate help to improve their health and that of their children.

2.5.2 Gender Dimensions of In Utero HAP Effects

To better understand the heterogenous impact of HAP on child health, we assessed how the impacts differed between boys and girls. Table 2.5 presents results of estimations disaggregated by gender.

Table 2.5: Results of disaggregated gender estimations

	(1) Boys	(2) Boys	(3) Girls	(4) Girls
Firewood	−0.490*** (0.180)		−0.498*** (0.181)	
Dirty		−1.352*** (0.475)		−0.984*** (0.338)
Constant	−1.201*** (0.166)	−0.245 (0.477)	−1.424*** (0.181)	−0.833** (0.351)
Observations	298	298	288	288
Number of districts	110	110	109	109

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

In Table 2.5, we see that in utero HAP from dirty fuel has a greater negative impact on height for age among boys than girls. In other words, male fetuses and boys are more sensitive to the effects of HAP in utero than girls. This conclusion agrees with what is largely known from both the medical and non-medical literature. Hsu et al. (2015), for instance, found that prenatal air pollution led to boys being diagnosed with asthma by age six more often than girls. Bose et al. (2018) also found that prenatal exposure to nitrate air pollution was associated with lung function disorders in children and the negative effect was more pronounced in boys than in girls. While the reasons for

the stronger effect of *in utero* HAP exposure in boys may be unclear, it has been observed that boys tend to have smaller airways in relation to their respiratory volumes while girls in early life, tend to have larger airways relative to their body size with lower airway resistance (Hsu et al., 2015; Clougherty, 2010). This is supported by findings that the male fetus tends to lag behind in lung development and its functional maturity compared to females of a similar gestation age (Liptzin et al., 2015; Torday et al., 1981). Pulmonary maturity has also been found to be higher among female infants than in male infants (Torday et al., 1981). Others have argued that female sex hormones have antioxidant properties which may be important in protecting the airways from the effects of pollution (Peter et al., 2015; Hsu et al., 2015; Bellanti et al., 2013) making the effects on girls smaller. These have been offered as biological reasons explaining why boys stand at a higher risk of the adverse effects of early exposures to air pollution. Thus, we conclude that males are more susceptible to pollution in utero as the effects on them is greater than on their female counterparts.

2.6. Conclusions

The results of this study clearly suggest that households using dirty cooking fuels are facing the risk of having stunted children by exposing mothers to HAP. It also points out that children of mothers with more years of schooling tend to have higher heights for age. We also found evidence that may support why earlier studies on heterogenous impacts of air pollution between gender. We conclude that households' continuous use of solid cooking fuels puts their health at risk; thus, they should consider this in their fuel decision making. The findings of this study clearly suggest that one of the main causes of child stunting is exposure to HAP in utero. The global efforts at reducing stunting and at meeting the related target under SDG goal two will be more effective if attention is paid to the type of cooking fuels households use, especially during pregnancy. In light of this, our study asserts that Ghana's current rural LPG promotion policy geared towards increasing LPG usage among rural residents can be a step in the right direction. Promotion of LPG in rural and urban area will discourage dirty fuel usage across the country and reduce the health risk of children.

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CHAPTER THREE

Risk Aversion and Clean Cooking Fuel Choice: An Empirical Study in Ghana

Abstract

Clean cooking remains an important policy objective in the bid to achieve sustainable development. Despite efforts at encouraging clean cooking fuel use, dirty fuel is still widely used in many developing countries. This study investigates the role of behavioral factors particularly risk aversion in the choice of cooking fuels. In addition, we investigate how the improvement of supply infrastructure and services mitigate the impact of risk preferences in fuel choices. By employing data from the recent round of the Ghana Living Standards Survey, we find that risk averse households are less likely to choose LPG as their cooking fuel. However, the effect is mitigated for households who live in districts with more supply infrastructure. Additional analyses reveal the influence of risk and time preferences in other household behavior.

Keywords

LPG; Risk aversion; Ghana; Firewood; Household behavior

3.1. Introduction

Clean cooking has gained increased attention as a strategy for sustainable development in developing countries. The use of clean cooking fuels plays an important role in reducing adverse health and environmental consequences associated with traditional biomass use. Indoor air pollution from the use of dirty fuels is estimated to cause more than three million premature deaths annually (World Health Organization [WHO], 2018). A large number of studies also report negative health effects of using such fuels and have advocated for clean cooking as alternatives (Bede-Ojimadu and Orisakwe, 2020). In response, several developing countries such as Ecuador, Peru, Ghana, South Africa, and India among others have taken measures to shift households' reliance on traditional cooking fuels to the use of cleaner fuels. Over the past decade and a half, countries have implemented various programs to encourage the use of cleaner fuels such as liquified petroleum gas (LPG) for cooking.

Despite the policy interventions to promote clean cooking fuel usage, dirty fuels which often produce high levels of air pollution are widely used in most developing countries. For instance, in Ghana, the latest national survey (Ghana Living Standards Survey VII) shows that about three-quarters (74.64%) of households still use dirty cooking fuels as their primary choice. Recent research further points out that the policy to promote LPG usage in rural areas has no suggestive effect in shifting from dirty fuels to LPG use (Adjei-Mantey and Takeuchi, 2019; Asante et al., 2018). Empirical studies in India also suggest that the use of dirty cooking fuels persists despite the program to subsidize clean cooking fuel use (Gupta et al., 2019; Malakar et al., 2018). Further investigation is required to provide relevant insights to shape policy and intervention strategies for promoting clean cooking fuels across developing and emerging economies.

This study explores the role of behavioral factors in determining cooking fuel choices. More specifically, we examine whether the individual preference for risk and time affects the choice of the primary cooking fuel between traditional and modern fuels. According to the behavioral economics literature, psychological factors influence a broad range of human decision-making scenarios. Bounded rationality, loss aversion, and bias toward the status quo are psychological reasons why individuals and households make seemingly unreasonable choices (Angner and Loewenstein, 2012). Psychological factors affect decision-making with regard to consumption and

saving (Dioikitopoulos et al., 2020), agriculture (Asravor, 2019), finance (Van Raaij, 2016), and adoption of information technology (Sriyabhand and John, 2014).

Regarding the adoption of energy-efficient technology, behavioral factors such as inertia, aversion to loss, or risk could act as barriers (Hesselink and Chappin, 2019). The shift from traditional cooking fuel, such as firewood, to LPG involves some level of risk that may invoke inertia or a resistance to adopt new technology for risk-averse households. First, there is a risk of unavailability of LPG when a household needs it. It poses a substantial risk, particularly in developing countries, where the supply chain of fuel is unstable. If there is a gas shortage at the nearest refill station, it means that this household cannot have fuel for cooking. The second risk factor for households is price volatility. The price of LPG is heavily influenced by the exchange rate and crude oil prices. Due to the high volatility of these factors, the price inevitably fluctuates. Price volatility is not a concern if the household uses firewood since it is available free of charge without monetary payment to many households. Third, the safety of using LPG is also a matter of concern. The concern has been fueled by historical and recent cases of gas explosions at both residences and refill stations. To avoid potential explosions associated with LPG use, risk-averse individuals will avoid choosing LPG. Based on the above reasons, we hypothesize that risk-averse individuals are less likely to choose LPG as their cooking fuel.

Time preference is another attribute that might affect cooking fuel use. Switching to LPG use has associated environmental and health benefits that may only be visible in the long term. As such, we hypothesize that patient individuals are more likely to choose LPG over dirty fuels. Impatient individuals would rather give due weight to the current benefit than that in the future. Thus, we examine whether time preference matters in the decision to choose LPG.

The contribution of this study is two-fold. First, we empirically examine the role of behavioral factors in the choice of household cooking fuel. Studies on the determinants of household cooking fuel in developing countries mostly focus on socio-economic factors such as income or poverty levels, education or literacy, rural or urban location of household, access to infrastructure, and supply of the fuels (see: Karimu et al., 2016; Mensah and Adu, 2015; Karimu, 2015). To the best of our knowledge, only a few studies explore the role of behavioral factors in choosing cooking fuel. By accounting for risk preferences, which the previous studies did not account for, this study reveals important behavioral factors that should be considered in any clean fuel promotion policy.

Second, we investigate whether the impact of risk aversion can be mitigated by improving supply reliability. Although several studies point out the importance of fuel availability in the promotion of LPG, how it relates to psychological factors has not been well examined in extant literature. By exploring the effect of improving fuel availability on risk-averse individuals, our study provides a significant implication for understanding how policy intervention works among heterogeneous households.

The remainder of this paper is organized as follows. Section 3.2 explains the risk associated with LPG use in Ghana. Section 3.3 reviews previous studies related to the topic. Section 3.4 describes the data and the empirical methodology. Section 3.5 presents the estimation results and discusses their interpretations. Section 3.6 concludes the paper and provides some policy implications.

3.2. Risks Associated with LPG Use in Ghana

In this section, we provide an overview of the three kinds of risks of choosing LPG in the context of households in Ghana: unstable supply, volatile prices, and explosive accidents. First, LPG is supplied to a household at refill stations located in different parts of the country. A household must find a refill station convenient to them and refill their cylinders when they run out of LPG. These refill stations are mostly privately owned and managed on purely commercial bases. Thus, the specific location of a refill station tends to be more influenced by commercial and profit-making motives. The refill stations operate under the regulation of the National Petroleum Authority (NPA), the regulatory body for the downstream petroleum sector in Ghana. The NPA issues licenses for the setting up and operation of LPG refill stations. The total number of refill stations in the country increased from 310 in 2011 to 653 by the end of 2018. While an increase of 110% over the period appears impressive, the number is hardly sufficient. Figure 3.1 shows the distribution of refill stations among districts. From the figure, it can be seen that 48 out of 170 districts in Ghana have no LPG refill stations at all. Any household that adopts LPG in these districts must travel to the nearest district with a refill station. Even if one lives in a district where there is a refill station, they could be living quite far from the location, and so commuting to refill may be inconvenient. In 88 districts, there are up to 5 refill stations. In fact, 30 out of these 88 districts had only one refill station. Thus, while the number of refill stations may have increased significantly over time, households in districts with fewer number of stations would consider that

it is risky to switch their primary fuel from traditional ones to LPG. Furthermore, it is common for households to face an LPG shortage. Asamoah et al. (2012) reports that the majority of consumers revealed that they have experienced shortages between four and eight times a year.

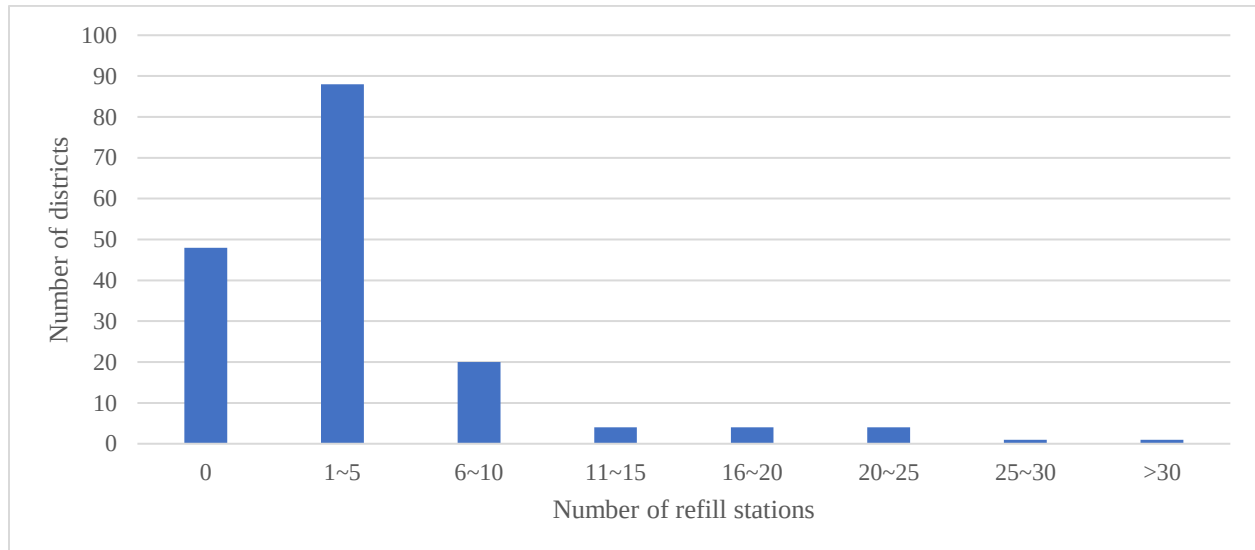


Figure 3.1: Distribution of LPG refill stations by number of districts⁶.

Source: Authors' computation using NPA data for 2019

Second, LPG prices had exhibited volatility despite those prices being historically determined through government policy. The government used to set the end user price of LPG per kilogram (kg), as was the case with other petroleum products. These prices were then reviewed occasionally. The government-determined prices of LPG were subsequently subsidized to cushion users and to encourage their use. In July 2015, the government of Ghana deregulated the downstream petroleum sector and withdrew from direct price setting and abolished subsidies on LPG and other petroleum products. Since then, the prices of LPG have been determined by suppliers based on factors such as the price of crude oil, exchange rate, and taxes and special levies. Irrespective of the body that sets the prices, price volatility remains. This is mostly due to the volatility in the input factors for

⁶ The number of districts covered in this figure are 170. This is the total number of districts that existed in Ghana before recent re-demarcation and creation of new districts increased the number of districts to the current 254. In some cases, the data from the NPA had not reflected the newly created districts and hence the decision to maintain the count of refill stations to cover the 170 districts that existed at the time.

price determination, particularly exchange rates and crude oil prices. Figure 3.2 depicts quarterly changes in LPG prices from 2011 to the first quarter of 2020.

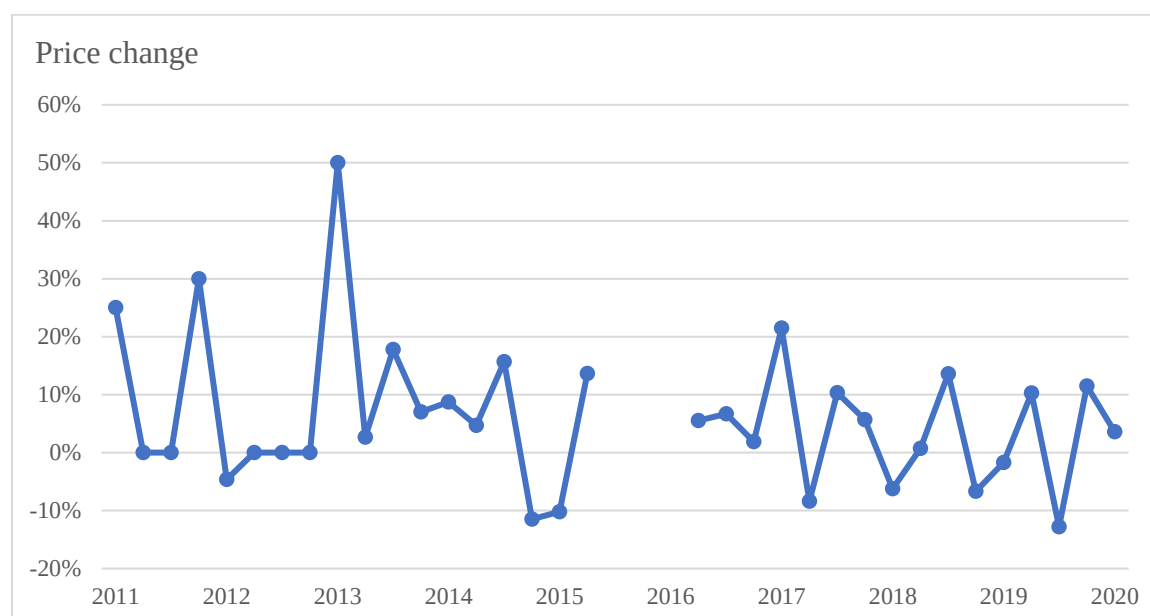


Figure 3.2: Quarterly price change, 2011 – 2020⁷

Source: Authors' computation from NPA data, 2020

Note: Data for 2015 Q3, Q4, and 2016 Q1 are unavailable.

Figure 3.2 indicates that the price of LPG is volatile, making it difficult for households to correctly predict future prices for planning. The difficulty in predicting prices could impede risk-averse households from switching to LPG. The data presented emphasize how the factors of LPG supply and prices could pose risks for households who are considering switching cooking fuel. For risk-averse households, price volatility could be a disincentive to adopt LPG as their primary cooking fuel.

Third, the risk of an LPG explosion is well known in Ghana. There were ten major reported explosions between 2014 and 2018, leading to 33 fatalities (Meteku et al., 2019). According to the risk assessment conducted by the NPA, 77.4% of LPG stations in the country do not meet safety

⁷ Besides the exchange rate, two key components of end user LPG price are the ex-refinery price which is based on cost, insurance, freight (CIF) and related charges, and the marketing margins. Price data from the NPA show that the ex-refinery price recorded an increase of 50% in 2013 Q1 while the margins increased by 20% in the same period; both having remained constant in the preceding 12 months. These, coupled with the usual volatile exchange rate accounted for the huge increase in LPG price in 2013 Q1.

standards (NPA, 2019; Reportingoilandgas, 2019). The safety issue is recognized by households as a serious risk in the adoption of LPG. Dalaba et al. (2018) interviewed households in the Kassena-Nankana Districts in northern Ghana. They found that most households expressed concerns about the safety of LPG: 85% of rural households and 80% of urban households agreed that cooking with LPG was dangerous. Similar safety concerns are not expressed in the case of firewood or charcoal use. These fuels are less likely to lead to explosions in the home and if fire from wood fuels gets out of control, households will find it is easier to douse the flames compared to fire from LPG that gets out of control due to the chemical composition of LPG.

3.3. Literature Review

Though the literature on the determinants of cooking fuel choice in developing countries is vast, only a small number of studies have dealt with the role of risk aversion.⁸ For example, Brooks et al. (2016) investigates the impact of cleaner cookstoves on biomass fuel use, time spent collecting biomass fuel, and cooking time in two Northern Indian states. Their analysis found that risk avoidance was positively correlated with the adoption of clean cookstoves both during the monitoring period and the week prior, while most risk-taking households were less likely to have used cleaner cookstoves in the week prior but had no significant effect in the monitoring period. However, the authors reported their measures of risk preferences to be crude, calling for further investigation into the role of risk preferences in adopting cleaner stoves. They measured risk avoidance by ownership of toilets in the household. Toilet ownership is considered to be remotely associated with risk preferences. However, it is also influenced by a host of other factors, especially in rural settings in developing countries, and hence may not appropriately represent risk preferences. It can be argued further that if households owned toilets as a safeguard against the health implications involved in not having one, then these households would also adopt clean cooking for the same reasons to avoid health risks. This argument notwithstanding, the findings point to the potential influence of the risk behavior of households on cooking fuel choices. Heutel (2019) explores how prospect theory explains people's decision to invest in energy efficiency, a decision associated with considerable uncertainty. Using choice experiments and a sample from

⁸ For reviews of the literature, see Lewis and Pattanayak (2012), Malla and Timilsina (2014), and Muller and Yan (2018).

the US population, the study found that loss-averse individuals are less likely to invest in energy efficiency, such as buying energy-efficient light bulbs or vehicles. The two studies discussed above differ significantly in their contexts. Brooks et al. (2016) focuses on India, a developing country where cooking fuel is a key component in household energy decision-making, whereas the study of Heutel (2019) is based in the US, a developed country that focuses on household appliances and vehicles rather than on cooking fuel. Nevertheless, both studies show that risk/loss aversion is important in household energy choices.

Atmadja et al. (2017) examines how personal discount rates explained the environmental health behaviors of households in rural India. The personal discount rate is a measure of time preference or impatience that explains how households view current costs in relation to future benefits. A high discount rate implies that the individual significantly discounts future benefits of an investment, thus rendering the present value of benefits low. This leads to low uptake of such investment as the costs to invest in the activity would often be higher than the present value of the benefits. The study found a significant and negative relationship between discount rates and environmental health behaviors, such as using mosquito bed nets, using latrines, adopting clean cooking fuels, treating drinking water, and even hand washing before eating and after using the toilet, which comes at a relatively lower cost to the household. Simply put, impatient people are less likely to invest in environmental health behavior, including cooking fuel choice. The importance of psychological factors in the context of fuel choice is also confirmed by studies using field experiments. Yu (2011) investigates how stove and behavioral interventions impacted acute respiratory infections (ARIs) in children under five in China. Behavioral interventions employed in this field experiment included providing education on the health risks associated with indoor air pollution and how to minimize exposure through alternative behavior. Specifically, education was provided on the sources of exposure, including sources attributed to behavior, health hazards of exposure, how stove and ventilation improvements reduced exposure, alternative behavior for stove use, and maintenance and stove use practices, including ways to handle fuel. The study found a significant reduction in ARI among the treatment groups. Notably, the study observed that the significant effect was more likely attributable to improved practices associated with stove use and better behavior to avert exposure than to improved cookstoves. Results from Atmadja et al. (2017)

and Yu (2011) suggest that a policy intervention to promote clean cooking would have a greater effect if it pays attention to how psychological factors work among heterogeneous households.

Our study also relates to the strand of papers that looks at the availability of cleaner cooking fuel. For example, Karimu et al. (2016) investigates the socio-economic factors that affect the adoption of LPG as the main cooking fuel in Ghana. Along with the strong effect of price and income, they found that a reliable supply of LPG significantly affects the probability of adoption. Sankhyayan and Dasgupta (2019) focus on the role of affordability and availability in the transition to modern fuel in India. Their results suggest that affordability is more dominant than availability: states with higher per capita incomes and literacy rates had greater access to LPG, while availability of the fuel was not an important driver of its adoption. However, their indicator of availability might not adequately capture the supply reliability. They measure availability with two variables: the number of LPG distributors per 1,000 square kilometer (km²) and road density. These measures of availability could be quite different from the experiences of households in their bid to use LPG. For example, if a 1,000 km² area has a specified number of distributors, albeit concentrated in a particular place and quite far from places of residence, the real experiences of households will likely vary with their locations. This could partly be the reason why LPG availability does not appear as an important variable in their study. In contrast, Dendup and Arimura (2019) conducts a study in Bhutan and found that distance to the nearest market negatively affects the choice of LPG. They interpret the distance to the market as the access to clean energy because households typically refill their empty LPG cylinder at the distribution depot located in the nearest market. Jagger and Jumbe (2016), in a study on the adoption of improved cookstoves in Malawi, find that households that had crop residue constituting a high share of cooking fuel tended to adopt improved cookstoves. Households with this feature typically belonged to the lowest income group. A large share of crop residue in household cooking fuel implied the scarcity of fuelwood or the lack of access to it and consequently, higher odds of adopting improved cookstoves. On the other hand, household forest ownership increased the adoption of improved cookstoves, signaling a desire to conserve its own forest resources. This implies that availability of wood for fuel had different impacts on the adoption of improved cookstoves depending on the household's resource ownership.

While the abovementioned studies incorporate the subjective or objective measure of availability in their model in explaining the adoption of clean cooking fuel, they do not address how the

availability matters to households with different risk preferences. This study fills the gap in the literature by examining how risk preference interacts with the availability of cleaner cooking fuel.

3.4. Data and Methodology

3.4.1 Data

The data for this study comes mainly from the seventh round of the Ghana Living Standards Survey (GLSS VII). The GLSS is a nationwide individual- and household-level surveys that collect data on demographics, economic, and social variables. It is conducted through face-to-face interviews and remains the most comprehensive source of household-level data in Ghana in terms of coverage and scope. The Ghana Statistical Service (GSS), a public agency with the necessary autonomy, conducts these surveys and provides official data on Ghana's economy. Enumeration areas (EAs) are defined by the GSS as the primary sampling unit and stratified among the administrative regions of the country to reflect the regional populations. From these EAs, households are selected as the secondary sampling unit. The survey for GLSS VII ended in October 2017, covering over 14,000 households and more than 55,000 individuals. Because our main interest is in the cooking fuel choice of the household, this study uses responses from household heads and their spouses as the major decision makers in a household. All but two variables in this study sourced their data from GLSS VII. Data on the ease of availability of LPG in the recent past within the district a household resides comes from GLSS VI (2012/2013), while data on the number of LPG refill stations in each district was gathered from the NPA (2019).

Table 3.1 reports the summary statistics. Risk preference is a binary variable, with 1 being *risk averse*, and 0 otherwise. Individuals are considered risk averse if they choose to (1) invest in a business where no loss of money is assured but would make low profits over (2) investing in a business where there is a small chance of losing money but potentially brings high profits. The majority of the sample (83%) are risk averse. Largely, the respondents showed consistency in risk preferences in their responses to other risk-related questions. About half of the sample (49%) are impatient. They prefer current benefits to future benefits all the time. A household is impatient if they exhibit no record of having preference for receiving a benefit in the future compared to the present. LPG is used by less than a fifth (17%) of the respondents and was easily available for purchase in the districts of residence of about half (49%) of the sample. Besides LPG, other major

cooking fuels used by households as primary fuels are firewood and charcoal representing 51% and 27% of respondents respectively. Information access, measured by ownership of a functional television or radio set, and electricity are available to a considerable proportion (71% and 74%, respectively). “Poor” and “very poor” households make up 16.4% and 13.1% respectively leaving about two-thirds of the sample being “non-poor”. Poverty status is measured as a categorical variable on the basis of daily subsistence. “Very Poor” households are those who live below the lower poverty line of Gh¢982 per adult equivalent per year while “poor” households live above the lower poverty line but below the upper poverty line of Gh¢1,760 per adult equivalent per year⁹ (GSS, 2018). “Non-poor” households, used as the reference category in the empirical analysis, are households that live above the upper poverty line. The lower poverty line represents the minimum amount needed to meet the nutritional requirement of a household member. Living below that amount suggests that even if the entire household budget is allocated to food, it is not enough to meet minimum nutrition requirement. The upper poverty line captures what is needed for both essential food and non-food consumption. Thus, households who are able to live above that are considered non-poor since they can meet their basic nutritional as well as non-food needs. In-between the “very poor” and “non-poor” are the “poor” households who have enough to satisfy their minimum nutritional requirement but not enough to meet all their basic non-food consumption needs.

In Ghana, LPG users have to go to a refill station to refill a cylinder when out of gas. Therefore, one of the factors that would be key to potential users would be whether it would be easy to purchase LPG to refill their cylinders. These refill stations are mostly privately owned, commercially run businesses and hence, the decision on where to site them are influenced by economic reasons. A household inevitably considers the availability of LPG within their locality of dwelling, and the possibility of fuel shortage in the future will affect their decision to switch to LPG. To capture this effect, we used data on the availability of LPG within the district of residence in the recent past from GLSS VI. The “availability” variable captures responses to the question on whether households found LPG available whenever they tried to purchase it in the past 12 months. Since the question is premised on households actually trying to purchase the fuel, responses capture their real experiences more than simply their perceptions about availability. As a

⁹ The average exchange rate was \$1: Gh¢4.4 in 2017

robustness check, we substituted this variable with the actual number of LPG refill stations in the district. The data were obtained from the NPA. By using households' experiences of availability of LPG when they attempted to purchase, in addition to the number of refill stations located in their district, we capture how easily available LPG is to the average household in the dataset.

Table 3.1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LPG	21,900	0.1745	0.3795	0	1
Risk-averse	21,415	0.8340	0.3721	0	1
Availability	21,682	0.4913	0.4999	0	1
Impatient	20,726	0.4922	0.5000	0	1
Education					
Basic	17,235	0.6574	0.4746	0	1
Secondary	17,235	0.1553	0.3622	0	1
Post-secondary	17,235	0.0403	0.1967	0	1
University	17,235	0.0434	0.2038	0	1
Urban	21,900	0.4010	0.4901	0	1
Poverty Status					
Poor	21,899	0.1642	0.3704	0	1
Very poor	21,899	0.1309	0.3373	0	1
Information	21,662	0.7080	0.4547	0	1
Electricity	21,899	0.7353	0.4412	0	1
# Stations	21,899	5.9288	8.4387	0	34
Firewood	21,900	0.5078	0.4999	0	1
Charcoal	21,900	0.2665	0.4421	0	1

3.4.2 Conceptual Model and Empirical Methodology

The theoretical underpinning of this study is the random utility theory, which assumes that the utility derived from the consumption of any commodity (cooking fuel) depends on observable and unobservable factors. A household, i , chooses from j cooking fuels where the bundle j includes clean fuel—in this case, LPG—and dirty fuels. Thus, with j options of cooking fuel available to the household, the household chooses LPG if the utility derived from using LPG (U_{LPG}) exceeds the utility from dirty fuels (U_{dirty}), as given below:

$$\Pr_i(LPG) = \Pr(U_{i,LPG} > U_{i,dirty}). \quad (3.1)$$

Therefore, we specify a model for explaining LPG choice as follows:

$$\Pr_i(LPG) = \beta_0 + \beta_1 R_i + \beta_2 R_i S_i + \beta_3 S_i + \beta_4 X_i + \varepsilon_i, \quad (3.2)$$

where R is risk aversion, S is the availability of fuel, and X denotes the other factors that might affect the choice, such as poverty status, level of education, and access to information. We interact risk aversion with the availability of LPG to understand how the effect of an individual's risk preference can be managed practically by a policy to promote a choice for LPG. Earlier studies have observed a potential association between poverty and risk aversion (Haushofer and Fer, 2014). It has been argued that poorer households tend to be less willing to take risks and more likely to discount future benefits. A correlation test of our explanatory variables, however, show that while a positive association is observed between poverty and risk aversion, the association is weak (coefficient: 0.006). With respect to education, a coefficient of -0.066 suggests more educated people tend to be less risk averse but the association is not strong either. Thus, the inclusion of risk preference in our model uncovers and explores new insights about cooking fuel choice that are potentially unrelated to socio-economic status. As previously mentioned, this is useful for the formulation of clean cooking policies.

Besides risk preference, time preference is another behavioral trait that captures individuals' levels of patience or preference for current over delayed benefits. Since reduced firewood use is helpful to environmental health, patient households will be more likely to choose the preservation of environmental health even though that potentially has delayed benefits. In other words, they will opt against firewood use now to prevent tree cutting and environmental degradation through the heavy pollution associated with firewood use. With respect to socio-economic variables,

availability of LPG represents the ease of obtaining the fuel and is expected to influence its use positively. Affordability is an important question in household fuel choice decisions. Due to the costs of LPG as a modern fuel compared to near zero monetary costs of alternatives such as firewood, poorer households are expected to be less likely to choose LPG compared with non-poor households. More educated people are expected to know the benefits of using modern fuels and hence will have a positive association with choosing LPG. Educated people tend to have higher opportunity costs of time and hence fuels such as LPG which cook faster and costs less time acquiring (as opposed to time spent in firewood collection) will be favored above alternatives. In addition, educated people are expected to appreciate the health dangers involved with persistent use of highly polluting fuels such as firewood and hence avoid these. Information is important to the choice of cooking fuels. Having access to information provides households the opportunity to learn about the dangers of using traditional fuels. In addition, through media campaigns on radio and TV, households learn about safe ways to handle and use LPG. As a result, the fears associated with LPG use will be assuaged through their access to information. At the time of this study, the NPA in Ghana was sponsoring campaigns on radio and TV educating the population on how to use LPG safely. Owners of a radio or TV are therefore able to benefit from these informational campaigns. Hence, access to information is likely to promote the use of LPG among households. Living in an urban area is expected to positively impact on choice of LPG as opposed to rural location. Urban centers tend to have comparably less supply of wood fuel. In addition, urban locations have better LPG supply infrastructure including accessible roads thus making the distribution of LPG easier in such locations. Similarly, having access to modern infrastructure such as electricity is expected to positively influence choice of LPG.

The probit estimation technique is employed to estimate Equation (3.2). We perform a correlation test of the variables, and it shows no strong correlation among any of the explanatory variables.

3.5. Results and Discussion

3.5.1 Effect of risk aversion on cooking fuel choice

Table 3.2 shows the results from the probit estimation of Equation (2). Table 3.3 shows the marginal effect of being risk averse (compared to not being risk averse) evaluated at (1) average level of LPG availability in one's district and (2) zero LPG availability in the district. Table 3.3 reveals that risk aversion has a negative and statistically significant effect on choosing LPG as the primary cooking fuel. A risk-averse household has a 5.2% lower likelihood of choosing LPG than a non-risk-averse household when there is an average level of LPG availability in their district. In the case of zero availability of LPG, the risk-averse household has a 5.7% lower likelihood of choosing LPG than a non-risk-averse household. Thus, by increasing LPG availability from a zero level to an average level, the probability of choosing LPG for risk-averse households increases by 0.5%. Given that the majority of Ghanaians (83% of the sample) are risk averse, this could yield substantial impacts at the national level. This result is consistent with our expectations that risk aversion hampers LPG usage. In contrast to the robust relationship between risk aversion and LPG usage among model specifications, time preference does not have any significant effect on the probability of choosing LPG.

From Table 3.2, LPG availability has a positive effect on the likelihood of choosing LPG, in line with previous findings (Karimu et al., 2016; Mensah and Adu, 2015). For the interaction between availability and risk aversion, the estimated coefficient suggests that the effect of availability becomes even higher for risk-averse households. The availability of LPG in their locality can increase their chances of choosing LPG. Thus, even though risk aversion prevails as a behavioral or natural trait, its negative impact on LPG usage can be partially offset by ensuring a stable supply. The result agrees with the general observation by Godoe and Johansen (2012) that personality dimensions and system-specific dimensions are important in adopting new technology. Our results differ from those of Sankhyayan and Dasgupta (2019), who find that availability is insignificant in determining the uptake of LPG. Their study measured availability using two variables: the number of LPG distributors per 1,000 km² and road density. Our measure of availability is based on individual perception and reflects each household's experience more precisely. This could partly explain why the effect of LPG availability is different.

Access to electricity and the ownership of a functioning radio or TV set enhances LPG usage. Radio and TV programs provide an opportunity for households to know about the benefits of clean cooking fuel. Access to information can lead them to choose LPG. Additionally, anxiety about the safety of LPG use can be alleviated through the information obtained from these media. Dendup and Arimura (2019) and Kumar et al. (2016) also find information and awareness to be crucial in the adoption of LPG, while Sehjpal et al. (2014) notes that household access to electricity could have an indirect positive effect on the choice of clean cooking fuels.

Poverty, education, and urban location influence the choice of clean cooking fuel. Compared to the non-poor households, the poor and very poor households are less likely to choose LPG. As opposed to no formal education, a higher level of education is associated with a greater likelihood of choosing LPG. Households in urban areas tend to choose LPG. These findings are consistent with those of previous studies, such as those by Karimu (2015) and Pope (2018).

In summary, our results suggest that appropriate measures can reduce the negative impact of risk aversion on the probability of choosing LPG as primary cooking fuel. First, making LPG easily and readily available can increase LPG usage, particularly for those who are risk averse. Second, policy actions, such as information provision through radio or TV notices, and nudges could be an effective way to give households a better impression of LPG use and ultimately help them to adopt it. Finally, a development strategy that simultaneously provides modern infrastructure, modern fuels, and information and communication media will increase the household's chances of choosing LPG and reduce the impact of risk aversion.

Table 3.2: Probit estimates of choice of LPG as a primary cooking fuel

	LPG		
	(1)	(2)	(3)
Risk-averse	-0.194*** (0.034)	-0.347*** (0.044)	-0.272*** (0.057)
Risk-averse $\times$ Availability		0.283*** (0.050)	0.162** (0.075)
Availability			0.092** (0.043)
Impatient	-0.005 (0.027)	-0.004 (0.027)	-0.005 (0.027)

Poor	-1.196*** (0.091)	-1.161*** (0.092)	-1.156*** (0.091)
Very poor	-1.283*** (0.165)	-1.234*** (0.165)	-1.228*** (0.165)
Education: Basic	-0.057 (0.048)	-0.062 (0.049)	-0.063 (0.049)
Education: Secondary	0.321*** (0.053)	0.321*** (0.054)	0.321*** (0.054)
Education: Post-secondary	0.939*** (0.070)	0.942*** (0.070)	0.945*** (0.070)
Education: University	1.246*** (0.070)	1.247*** (0.070)	1.250*** (0.070)
Information	0.626*** (0.045)	0.617*** (0.045)	0.614*** (0.045)
Electricity	0.975*** (0.069)	0.976*** (0.069)	0.974*** (0.069)
Urban	0.795*** (0.029)	0.770*** (0.029)	0.762*** (0.030)
Constant	-2.565*** (0.093)	-2.538*** (0.093)	-2.594*** (0.097)
Observations	16,182	16,042	16,042

Notes: This table shows the results of probit estimation, with standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 3.3: Marginal effects of risk aversion on LPG choice as a primary cooking fuel

	LPG	
	(1)	(2)
	At average LPG availability	At zero LPG availability
Risk-averse	-0.052*** (0.012)	-0.057*** (0.012)
Observations	16,042	16,042

Notes: This table shows the marginal effect of being risk averse compared to non-risk averse, with standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

3.5.2 Robustness and Validity Checks

In this subsection, we examine several analyses to confirm the robustness of our results. First, we replace the LPG availability with the number of refill stations in each district. Second, we employ firewood usage as the dependent variable instead of the LPG.

Table 3.4 reports the probit estimation results when the number of refill stations in each district is used as a measure of availability. The results are in line with the main results. The effect of risk aversion on choosing LPG is negative and significant while increasing the number of refill stations has a positive relationship with LPG choice even for risk-averse households. Next, we employ firewood usage as the dependent variable instead of LPG. The results are reported in Table 3.5. We find a positive and statistically significant coefficient for risk aversion. In other words, risk-averse people are more likely to choose firewood as their cooking fuel. Furthermore, the effect is countered by LPG availability, as shown by the negative coefficient for the interaction term.

Table 3.4: Probit results: LPG choice

	LPG	
	(1)	(2)
Risk-averse	-0.496*** (0.038)	-0.229*** (0.051)
Risk-averse × # Stations	0.031*** (0.002)	0.010*** (0.003)
# Stations		0.023*** (0.003)
Impatient	0.012 (0.027)	0.002 (0.027)
Poor	-1.128*** (0.092)	-1.099*** (0.092)
Very poor	-1.224*** (0.165)	-1.181*** (0.165)
Education: Basic	-0.086* (0.049)	-0.090* (0.049)
Education: Secondary	0.288*** (0.054)	0.278*** (0.054)
Education: Post-secondary	0.942*** (0.070)	0.951*** (0.071)
Education: University	1.224*** (0.070)	1.225*** (0.070)
Information	0.592*** (0.045)	0.582*** (0.045)
Electricity	0.944*** (0.070)	0.934*** (0.070)
Urban	0.600*** (0.031)	0.550*** (0.032)
Constant	-2.345*** (0.094)	-2.562*** (0.099)
Observations	16,182	16,182

Notes: This table shows the results of probit estimation, with number of refill stations representing availability of LPG. Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 3.5: Probit results for firewood as a primary cooking fuel

	Firewood		
	(1)	(2)	(3)
Risk-averse	0.085** (0.035)	0.300*** (0.040)	0.188*** (0.048)
Risk-averse $\times$ Availability		-0.448*** (0.041)	-0.237*** (0.065)
Availability			-0.169*** (0.040)
Impatient	0.016 (0.025)	0.020 (0.025)	0.022 (0.025)
Poor	0.784*** (0.037)	0.738*** (0.037)	0.730*** (0.037)
Very poor	0.943*** (0.051)	0.860*** (0.052)	0.849*** (0.052)
Education: Basic	-0.056 (0.040)	-0.051 (0.040)	-0.050 (0.040)
Education: Secondary	-0.355*** (0.050)	-0.365*** (0.050)	-0.365*** (0.050)
Education: Post-secondary	-0.791*** (0.083)	-0.824*** (0.084)	-0.831*** (0.084)
Education: University	-1.127*** (0.097)	-1.159*** (0.098)	-1.164*** (0.098)
Information	-0.225*** (0.030)	-0.207*** (0.030)	-0.203*** (0.030)
Electricity	-0.705*** (0.033)	-0.700*** (0.033)	-0.697*** (0.033)
Urban	-1.368*** (0.026)	-1.343*** (0.026)	-1.332*** (0.026)
Constant	1.022*** (0.060)	1.003*** (0.060)	1.090*** (0.064)
Observations	16,182	16,042	16,042

Notes: This table shows the results of probit estimation, with standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3.6. Additional analyses

In addition, we carried out analyses to check whether the variables for risk and time preferences play a role in the decision-making of other activities that contain some degree of risk. The objective of the additional analyses is to investigate the effect of behavioral factors of risk and time preferences on other household choices. In other words, we ask the question: do households' risk

preferences determine other household choices or risk preferences influence fuel choices without influencing other household decisions? A significant effect of risk aversion in other household choices would validate the relationship found in this study with regards to cooking fuel choice as it would emphasize that household decisions largely depend on this behavioral trait. The results are summarized in Table 3.6. We examined three household behaviors: contraceptive use, e-commerce adoption, and job change. Risk-averse individuals are likely to use contraceptives to delay or prevent pregnancy, while impatient people are likely not to use them. Risk-averse people are less likely to use e-commerce, probably due to their apprehensions regarding online security and system reliability. Online shopping is very different from traditional face-to-face business. Risk-averse people are also less likely to change jobs. Once people are accustomed to their jobs, they will be less willing to seek to change jobs, all things being equal. The question on the job change is asked only to persons who had indicated that they wished to have a job change hence the fewer observations than other models. The results in Table 3.6 show that risk-aversion affects these three areas of decision-making in a way expected as above. Risk-averse individuals tend to use contraceptives, avoid e-commerce, and do not tend to change their jobs. The results suggest that individual decision-making depends on their risk preferences. This finding provides evidence that supports the validity of the risk aversion variable used in the main analysis.

We also examined whether risk aversion matters for decisions related to electricity usage. First, risk aversion can affect the use of backup electricity sources in two ways. On one hand, risk averse households might demand an alternative electricity source as a backup for disruption in their primary source (usually the national grid). On the other hand, they may be less likely to have an alternative source since the purchase of a backup generator, a solar panel, or a local mini-grid involves some risks as these are unfamiliar technology for those who rely on the national grid. The results from columns (1) and (2) of Table 3.7 appear to favor the latter and suggest that risk-averse people are less likely to have additional electricity sources. Second, we also explore if risk-averse and impatient individuals are more likely to use energy-saving light bulbs exclusively for lighting. In this instance, the result was not consistent with our expectations that impatient people usually do not invest in new technology that requires higher initial cost but provide higher future benefits. A comprehensive analysis of how awareness is established in such instance is required.

Table 3.6: Other potentially risky events

	Contraceptives		E-commerce		Job change	
	(1)	(2)	(3)	(4)	(5)	(6)
Risk-averse	0.066** (0.027)	0.117*** (0.031)	-0.141** (0.053)	-0.144** (0.061)	-0.160*** (0.054)	-0.139** (0.062)
Impatient		-0.113*** (0.023)		0.004 (0.050)		0.010 (0.047)
Poor		-0.024 (0.036)		-0.177* (0.092)		-0.052 (0.072)
Very poor		-0.026 (0.044)		-0.329*** (0.127)		0.016 (0.083)
Education: Basic		-0.160*** (0.037)		-0.014 (0.096)		-0.011 (0.075)
Education: Secondary		-0.109** (0.045)		0.301*** (0.106)		0.137 (0.092)
Education: Post-secondary		-0.159** (0.066)		0.700*** (0.120)		0.413*** (0.131)
Education: University		-0.024 (0.063)		0.829*** (0.116)		0.170 (0.140)
Information		0.145*** (0.029)		0.049 (0.068)		-0.217*** (0.056)
Electricity		0.099*** (0.031)		0.004 (0.075)		0.160** (0.062)
Urban		0.018 (0.025)		-0.077 (0.055)		0.094* (0.053)
Constant		-0.947*** (0.056)		-2.123*** (0.132)		-1.305*** (0.111)
Observations	21,379	16,158	21,411	16,179	7,913	5,930

Notes: This table shows the results of probit estimation, with standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 3.7: Electricity-related outcomes

	Backup power		Energy-saving light bulbs	
	(1)	(2)	(3)	(4)
Risk-averse	-0.187*** (0.027)	-0.174*** (0.030)	0.303*** (0.027)	0.300*** (0.031)
Impatient		0.007 (0.023)		0.121*** (0.025)
Poor		-0.098** (0.041)		-0.307*** (0.040)
Very poor		0.010 (0.055)		-0.469*** (0.053)
Education: Basic		0.015 (0.040)		-0.007 (0.042)
Education: Secondary		0.050 (0.047)		-0.023 (0.049)
Education: Post-secondary		0.150** (0.064)		-0.130* (0.068)
Education: University		0.137** (0.063)		-0.161** (0.065)
Information		0.126*** (0.032)		0.094*** (0.033)
Electricity		0.122*** (0.025)		0.029 (0.027)
Urban		-0.533*** (0.056)		0.366*** (0.057)
Constant		-0.174*** (0.030)		0.300*** (0.031)
Observations	15,739	12,726	15,739	12,726

Notes: This table shows the results of probit estimation, with standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

A potential limitation of this study is the absence of LPG price in the estimation model. While there is limited data availability, the prices of petroleum products in Ghana are largely the same across different suppliers. In other words, all households are likely to face prices from suppliers that do not significantly differ from one another. Karimu et al. (2016) demonstrates that omitting the variable does not significantly bias the results of their studies. In Ghana, the distance to a refill station is likely to represent a more relevant differential cost of LPG to households and hence is potentially of greater importance for their decision-making with regard to primary cooking fuel. Sankhyayan and Dasgupta (2019) also find that price was not even a significant determinant in the uptake of LPG as cooking fuel. The evidence suggests that exclusion of LPG price from the model might not decrease the validity of the analysis.

3.7. Conclusion and Policy Recommendations

This study focused on risk and time preference as factors explaining household cooking fuel choices. The obtained results suggest that risk preferences play a significant role in the choice of LPG as primary cooking fuel, while time preferences do not have a significant impact. Risk-averse individuals were found to be less likely to choose LPG as their primary cooking fuel. However, if households find LPG easily available upon demand, then even risk-averse individuals will be more inclined to choose LPG. We also found the influence of access to and adoption of modern infrastructure in the form of electricity to be a significant factor in influencing the probability of choosing LPG. Meanwhile, access to information was also shown to play an important role in deciding to choose LPG as cooking fuel.

Based on the above findings, we recommend that the government and policymakers should pay attention to the fact that many households in Ghana are risk averse and are less likely to shift to LPG as primary cooking fuel. Policy that makes LPG easily available might help mitigate the reluctance of risk-averse households toward cleaner cooking fuel choices. Furthermore, refill stations should be more evenly spread within a district to ensure easier access by households. This could be made possible by a social policy decision to provide economic incentives including but not limited to tax rebates or other non-fiscal incentives to LPG marketing companies to set up refill outlets in districts that have none or inadequate refill stations. An LPG supply system that delivers fuels to households on their premises promptly and reliably will reduce households having to travel to refill stations. Such a system will be particularly useful in promoting LPG use. The findings further suggest the importance of public awareness of the adverse health implications of continued use of heavy polluting fuels given that households tend to choose fuels with less risk. This could contribute significantly to a shift towards LPG use.

The evidence presented in this paper also suggests that development planning should be more comprehensive rather than disaggregated into individual components that are isolated from one another. Households that are electrified and have access to information are likely to choose LPG. This suggests that the response to LPG promotion policy will be less effective if households remain without access to electricity. The simultaneous provision of LPG infrastructure, provision of electricity, and information access will yield better results, thereby promoting the clean cooking agenda.

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CHAPTER FOUR

Does Free Distribution of Equipment Work? Measuring the Spill-Over Impacts of Ghana's Rural LPG Promotion Program

Abstract

Transition from dirty cooking fuels to cleaner ones 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 matching with difference-in-differences techniques, we find that the program had no significant spill-over impacts on primary household cooking fuel; LPG use did not increase, and dirty fuel 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.

Keywords

LPG; Dirty fuel; Ghana; Poverty; Rural LPG Promotion Program; Firewood

4.1 Introduction

Household air pollution is responsible for 3.8 million premature deaths in the world every year (World Health Organization (WHO), 2018). The risk is particularly high in developing countries, where many households still cook using solid fuels (e.g., wood, crop waste, charcoal, coal, and dung). 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 stunting in children (Adjei-Mantey and Takeuchi, 2021; WHO, 2018). 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. 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 Liquefied Petroleum Gas Promotion Program (RLPGPP), which aims to accelerate the uptake of LPG in rural communities. Under this policy for household energy transition, selected rural households are provided filled LPG cylinders and cookstoves with complementary accessories free of charge.

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. (2016) have argued that initial costs could be prohibitive for some households, thereby inhibiting them from making the transition to cleaner cooking fuel. Thus, the RLPGPP is expected to reduce reliance on firewood as the primary cooking fuel of rural residents. Furthermore, if firewood use is accordingly reduced among rural households, two key outcomes are expected. 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.

To achieve economic efficiency and better resource allocation, it is important to evaluate and measure the effects of such programs, particularly in developing countries. This chapter evaluates the spill-over impact of Ghana's LPG distribution program on rural households using

a nationally representative sample. Although some studies explore the impact of similar programs in developing and emerging market economies (Gupta et al., 2019; Calzada and Sanz, 2018; Pollard et al., 2018; Kimemia and Annegarn, 2016; Andadari et al., 2014), there is little evaluation of the policy at the nationwide level. While Asante et al. (2018) evaluated the effects of the RLPGPP in the Nkoranza North District of Ghana, the focus was limited to one district, and the analysis used a qualitative approach. This chapter 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 programs such as the RLPGPP have the potential to reduce poverty, studies that empirically test the poverty impacts are scarce. This chapter fills this research gap by providing evidence from empirical data on the fuel transition program's impact on poverty reduction.

While the RLPGPP is potentially beneficial to rural communities, it is essential to evaluate the program to assess whether its objectives are fulfilled and whether the allocation of limited resources is justifiable. The program has been implemented for several years, but its achievement has yet to be assessed. As the main goal of the program was to aid the transition to clean cooking fuel, this study aims to evaluate the impact of the RLPGPP on primary cooking fuel choice. Furthermore, we 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 its uniqueness in 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 (Gupta et al., 2019) while in Peru, vouchers to buy LPG cylinders are offered (Calzada and Sanz, 2018; Pollard et al., 2018); in both cases, households ought 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.

The remainder of the chapter is organized as follows. Section 4.2 discusses the background of the RLPGPP and the study hypothesis. Section 4.3 reviews the relevant literature. Section

4.4 explains the data and the empirical methodology of the study. The results are discussed in Section 4.5. Finally, section 4.6 concludes the chapter.

4.2 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 (Ahunu, 2015). 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.¹⁰ 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.

In 2013, the Ministry of Energy started the pilot phase of the RLPGPP. As mentioned in the previous section, 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., Karimu et al., 2016; Karimu, 2015; Mensah and Adu, 2015), 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. It is

¹⁰ The government later removed levies and introduced subsidies for domestic LPG users.

yet to be determined, however, 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 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.

Figure 4.1 shows the number of LPG cylinders and cookstoves distributed up to 2017 under the program.¹¹ By the end of 2017, 149,500 cylinders and 118,360 cookstoves with accessories, including gas regulators and gas tubes, had been distributed in 50 beneficiary districts across the country.¹² As shown in the figure, more than half of the total distributions occurred in 2016.

¹¹ 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.

¹² 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.

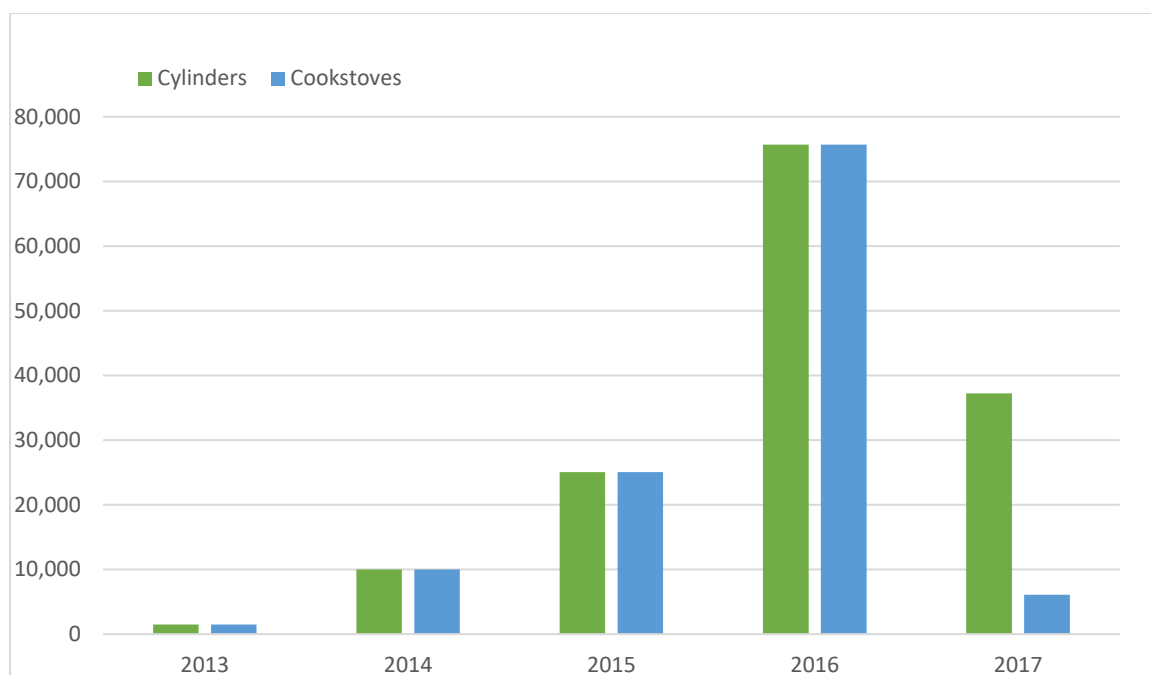
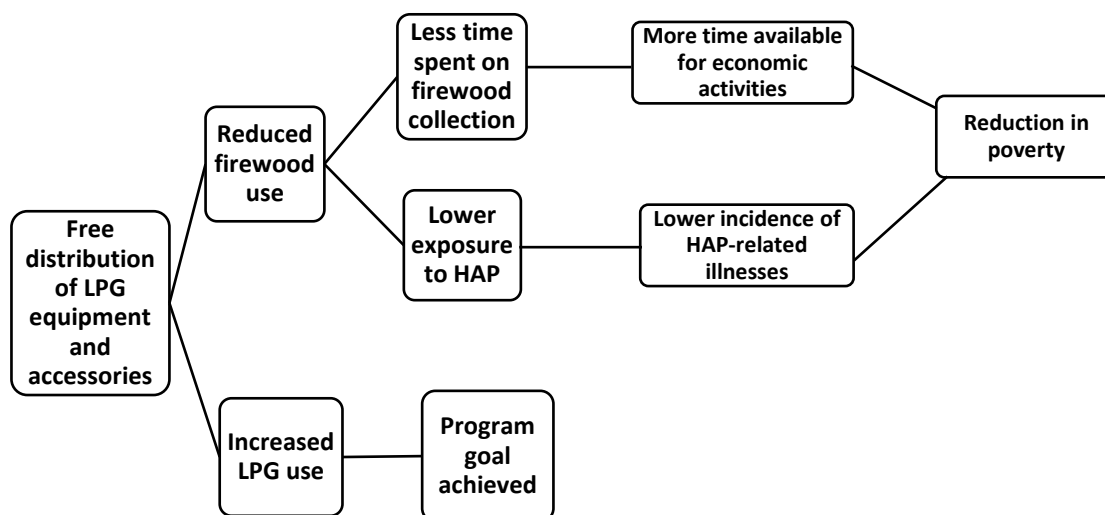


Figure 4.1: Amount of LPG equipment distributed under the RLPGPP

Source: Ghana's Ministry of Energy (2018)

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 Figure 4.2. 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. These changes could eventually lead to poverty reduction through improved health, labor force participation, and productivity.



Note: HAP stands for household air pollution.

Figure 4.2: Framework of the study

4.3 Literature Review

Several studies have evaluated the effect of LPG programs in developing countries. For example, Andadari et al. (2014) evaluated the impact of a fuel conversion program in Indonesia on energy poverty after the government discontinued subsidies on kerosene and subsidized LPG instead. They found that LPG consumption increased after the implementation of the program, although there were marginal increases in electricity and traditional biomass usage due to subsequent increases in the prices of kerosene. The study also found that the program did not substantially reduce the number of energy-poor people but was useful in lowering extreme energy poverty. Medium- to high-income households in urban and suburban areas benefited the most from the fuel conversion program.

Calzada and Sanz (2018) examined a public program for poor households in Peru to replace traditional stoves with LPG by providing monthly vouchers that households could use to exchange empty cylinders for fully filled ones. Using propensity score matching (PSM), the study found that households participating in the program used LPG to cook meals 33–38% more than the control group. However, based on a subsample analysis of households that owned LPG cookstoves before participating in the program, there was no evidence that the program increased the usage of LPG stoves for cooking except for a few beneficiaries who exchanged their vouchers every month. The study also found that beneficiaries in lower-income quartiles significantly increased their LPG usage, while there was no significant change in LPG

usage for beneficiaries in higher-income quartiles. Some beneficiaries, particularly those in higher-income quartiles, used modern fuels together with traditional fuels. In an evaluation of the same public program in Peru, Pollard et al. (2018) reported that more than 95% of total households practiced fuel stacking with traditional biomass-burning stoves, and less than 5% of households exclusively used LPG.

Kimemia and Annegarn (2016) examined a program in Atteridgeville township in Tshwane, South Africa, seven years after its implementation in 2006. The program distributes LPG kits with a free first fill of gas to beneficiaries. The study found that the program was successful in replacing combustion fuels among beneficiaries. LPG was the second most crucial energy source for households after electricity for both cooking and heating. The study also found that although the monthly subsidy helped to make electricity the primary energy source for residents, during the six years following implementation of the program, the role of paraffin and wood as secondary fuels for cooking diminished and was taken over by LPG. The study suggests that if some form of subsidy for LPG refills were made available, as is the case for electricity, the use of LPG would become more sustainable among beneficiaries.

Gupta et al. (2019) conducted a survey in rural north India to examine the persistence of solid fuel use despite increases in the ownership of LPG equipment. The Indian government has a program to facilitate rural households' LPG usage by providing free cylinders, regulators, and connecting pipes. Households have the option of obtaining the first refill and a cookstove as a loan to be repaid. Following the program, three-quarters of rural households in the study areas owned LPG, but almost all of them also had a stove using solid fuel. The study found that most households that owned both cooking fuel types used solid fuel the day before the survey (37% used solid fuel and LPG, while 36% used solid fuel only). Household economic status, relative fuel costs, gender inequality, and beliefs about ease of use and food taste, among other factors, contributed to the high rate of solid fuel use.

In the case of Ghana, Asante et al. (2018) 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.

The Research Directorate of the Ministry of Energy in Ghana has also conducted a monitoring and evaluation exercise of the RLPGPP in the Asante Akim North District (Ministry of Energy, 2018). While it is unclear whether beneficiaries still used their LPG cylinders at the time of monitoring, the frequency of LPG usage in a day was found to be lower than that of cooking in a day. Approximately 90% of respondents confirmed having an alternative fuel source for cooking, with nearly 75% of them using firewood and the rest using either charcoal or both firewood and charcoal. At least in the Asante Akim North District, the program has not led to a complete switch from dirty fuel use for cooking. The report found that only 22.9% of respondents replaced firewood with LPG in their households.

The results of Asante et al. (2018) and the Ministry of Energy (2018) on the RLPGPP in two different districts are similar. The findings show that the RLPGPP's impact on promoting the uptake of LPG as a primary household cooking fuel has been weak in the beneficiary districts studied. As these studies are based on evaluations of single districts, an assessment of the program using nationwide data is necessary to draw firm conclusions about the program's impact. Similarly, most previous studies in other countries examine the effect in selected districts (Pollard et al., 2018; Calzada and Sanz, 2018; Kimemia and Annegarn, 2016). Therefore, this study's evaluation of the nationwide impact fills the gap in the literature.

A key feature of Ghana's RLPGPP is its focus on rural households. It appears to be difficult for rural residents to shift to exclusive LPG use (Malakar et al., 2018) or even combined fuel use, although they have access to a government-assisted program. Other studies have not exclusively focused on rural residents. Andadari et al. (2014), for example, 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.

4.4 Data and Empirical Methodology

4.4.1 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 9,327 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 household data 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 not uncommon 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 rather than a household-level impact. 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 2017.¹³ 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.

¹³ The average exchange rates were \$1:Gh¢2.07 for 2013 and \$1:Gh¢4.4 for 2017.

Table 4.1: 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

^aA few households recorded a negative net income mostly due to losses they incurred from their non-farm enterprises.

Table 4.1 reports the summary statistics of the data 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. Meanwhile, 93% of households used dirty fuels, comprising mostly firewood and charcoal. The average proportion of poor households was 31.7%, while the very poor made up 12.5% of households. Approximately one-third of districts have benefitted from the RLPGPP implementation thus far. As shown in the last row, a district has 2.776 stations for refilling LPG cylinders on average. In other words, an average district has less than three refill stations.

4.4.2 Methodology

4.4.2.1 Matching with difference-in-differences

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 (Rosenbaum and Rubin, 1983). The probability $P(x)$ is equivalent to the propensity score:

$$P(x) = \Pr(W=1|x). \quad (4.1)$$

Equation (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 matching¹⁴ include the percentage of households that used firewood and that of households that used dirty fuel as primary cooking fuel in the baseline, as well as the district location based on the ecological zone.¹⁵

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 equation (4.2):

$$\Delta Y_{it} = \beta D_{it} + \gamma X_{it} + \varepsilon_{it}, \quad (4.2)$$

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.

4.4.2.2 Instrumental variable approach

As an additional method, we employ an instrumental variable (IV) approach to address potential endogeneity and appropriately measure the impacts. An instrument must be correlated with the endogenous regressor—in this case, the treatment variable—but not with the outcome

¹⁴ The results of balancing tests for PSM are reported in Appendix A.

¹⁵ The Ghana Statistical Service classifies enumeration areas into ecological zones—coastal, forest, savannah, and the GAMA (Greater Accra Metropolitan Area).

variable beyond its effect through the endogenous variable. As our instrument, we employ an indicator for swing districts that reflects the difference in votes in a particular district. Specifically, for each district, we calculate the absolute value of the difference between votes obtained by the governing party and the leading opposition party and divide it by the total valid votes cast in the general elections of 2012, one year before the implementation of the RLPGPP. In other words, the indicator for swing district Z is formulated as follows:

$$Z_i = \frac{|VotesA_i - VotesB_i|}{Total\ Votes_i}, \quad (4.3)$$

where $VotesA$ and $VotesB$ denote the number of votes obtained by the governing and main opposition parties in the district, respectively, and $Total\ Votes$ denotes the number of total valid votes cast in the district.

On the one hand, if the value of Z is low for any district, then that district is considered as a swing district—people could vote in favor of either party. The party in power is likely to select such a district as the program target to win more votes in the next election. On the other hand, if Z is high for any district, then that district is dominated by one of the parties. Hence, the district is less likely to be treated for political reasons because it would be much more challenging to alter citizens' voting patterns; thus, treating them for political reasons is not likely to yield the expected political result. Ghana operates a multi-party democracy wherein presidential and parliamentary elections are held every four years. However, only two of the many registered political parties are widely regarded as leading parties. These two, the National Democratic Congress and the New Patriotic Party, have been the only parties to take turns to govern the country since the current democratic dispensation started in 1992 with the adoption of a new constitution. When one party is in power, the other is unambiguously considered the leading opposition party. Except for the first elections under the current republic in 1992, when these two parties together received 88.7% of valid votes, and the elections in 2000, when they jointly obtained 92.8% of votes, all other elections have garnered more than 97% of votes cast for the two parties combined. The current parliament, which is the legislative body, has representatives from only these two parties. In the 2012 elections, from which we construct our instrument indicator, the two parties obtained a combined 98.44% of votes cast. Thus, by using votes obtained by these two parties in the construction of Z , we assure that the instrument does not leave out any significant votes that could have influenced which party won the elections in a district.

As this turns out to be a weak instrument and to avoid the bias of using two-stage least squares in the presence of weak instruments, coupled with the practical difficulty of obtaining a stronger instrument, we use limited information maximum likelihood (LIML) estimation. In the LIML IV estimation, equation (4) is estimated in a first-stage regression followed by a second-stage regression, as shown in equation (5). Our ultimate regression of interest is equation (5), where β shows the impact of the RLPGPP on our outcome variable of interest.

$$W = \gamma_0 + \gamma_1 Z + \gamma_2 X + \eta \quad (4.4)$$

$$Y = \beta_0 + \beta_1 W + \beta_2 X + \varepsilon \quad (4.5)$$

where Y is the outcome variable; W denotes the treatment variable, whose impact we aim to measure; X denotes a vector of explanatory variables; and Z is the IV.

4.4.3 Robustness Checks

To test for the robustness of our findings, we perform several analyses by considering several dependent variables to check the robustness of the results from our main variables. For the fuel choice model, we consider the percentage change in the average household LPG expenditure in the district as an alternative dependent variable. If there is a significant switch from dirty fuels to LPG between the pre intervention and post intervention periods, there should be a corresponding change in LPG expenditure over the two periods. We check this by measuring the impact of the RLPGPP on household LPG expenditure. The LPG expenditures in both periods are deflated by the price index and the 2005 purchasing power parity. For the poverty analyses, we consider whether the program yielded a spill-over impact on the proportion of residents employed in the district. The battery of robustness estimations is conducted using the matching with DID approach discussed in this section.

4.5 Results and discussion

4.5.1 Spill-over Impact of the RLPGPP on Cooking Fuel Choice

Table 4.2 reports the DID estimates after matching. In all model specifications, the coefficients for the DID indicator are not statistically significant. The results suggest that the

RLPGPP has not led to an increase in LPG use or a decrease in firewood/dirty fuel use in beneficiary districts. Similar results are obtained by using an IV approach.

Based on these results, we find no evidence that the RLPGPP has achieved its stated objectives after four years of implementation. Our finding is consistent with reports from field surveys conducted in beneficiary districts. As mentioned in Section 3 of this paper, Asante et al. (2018) 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 only 10% of beneficiaries still used their LPG cylinders 18 months after the program was implemented in that district; all respondents continued to use fuelwood as their primary cooking fuel, despite benefiting from the program. As mentioned in Section 3, the Ministry of Energy (2018) 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.

Our results are in contrast with those of Calzada and Sanz (2018) 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 results are also contrary to the findings of two previous studies (Imelda, 2020; Kimemia and Annegarn, 2016). In the case of South Africa, Kimemia and Annegarn (2016) 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 (2016), Imelda (2020) 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 (2018) and Toncoso and Da Silva (2017) on the adoption of LPG and that of Bensch et al. (2015) on the uptake of improved cookstoves.

Table 4.2: Effects on fuel choice

	Δ LPG use		Δ Firewood use		Δ Dirty fuel use	
	(1)	(2)	(3)	(4)	(5)	(6)
DID	0.002 (0.019)	0.004 (0.018)	0.024 (0.033)	0.017 (0.033)	-0.006 (0.019)	-0.007 (0.016)
Firewood use (Baseline)		0.173*** (0.057)		-0.188* (0.103)		
Dirty fuel use (Baseline)						-0.598*** (0.086)
Forest zone		-0.072** (0.028)		0.046 (0.050)		0.061** (0.024)
Savannah zone		-0.092*** (0.031)		0.144** (0.055)		0.097*** (0.025)
Constant	0.016 (0.012)	-0.054 (0.040)	-0.083*** (0.021)	-0.011 (0.072)	-0.012 (0.013)	0.484*** (0.076)
Observations	118	118	118	118	108	108
R-squared	0.000	0.095	0.005	0.082	0.001	0.324

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.

Table 4.3: Effect on gas expenditure

Variable	(1) % Δ Gas expenditure	(2) % Δ Gas expenditure
DID	8.727 (8.592)	8.437 (7.865)
Constant	4.529 (6.479)	4.099 (5.930)
Observations	51	51
R-squared	0.021	0.023

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Prices are adjusted by the price index (1) and 2005 purchasing power parity (2).

4.5.1.1 Impact on fuel choice—Alternative dependent variable

Table 4.3 shows the impact of the RLPGPP on the percentage change in average household LPG expenditure in the district. Neither model shows a significant impact of the program on how much households spent on LPG between the pre- and post-intervention periods. This confirms the main findings in Table 4.2 that there is no evidence that the program yielded a significant spill-over impact on fuel choices. As explained, a significant change in fuel choice toward LPG was expected to lead to a significant change in household LPG expenditure. However, that is not the case, as seen from Table 4.3.

4.5.1.2 Results from IV estimation

Table 4.4: Impact on fuel choice (OLS and LIML IV)

Dependent variable	Δ LPG use		Δ Firewood use		Δ Dirty fuel use	
	(1)	(2)	(3)	(4)	(5)	(6)
DID	-0.008 (0.021)	0.261 (0.234)	0.069 (0.044)	-0.284 (0.358)	0.008 (0.021)	-0.222 (0.194)
Constant	0.082*** (0.011)	0.003 (0.071)	0.678*** (0.025)	0.109 (0.107)	0.918*** (0.011)	0.336*** (0.119)
	OLS	IV	OLS	IV	OLS	IV
Observations	163	161	163	161	163	161

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

Table 4.4 shows the effects of the RLPGPP on fuel choice. Ordinary least squares (OLS) results are reported in columns (1), (3), and (5) as a comparison with the results from the IV method reported in columns (2), (4), and (6). The OLS method produces inconsistent estimates in the presence of endogenous regressors, as the results are not consistent with expectations. The IV method improves the findings by producing results with consistent signs. While the expected signs are observed in the IV estimations, there is no statistically significant impact of the RLPGPP on fuel use in treated districts. In other words, from columns (2), (4), and (6), the program might have led to an increase in LPG use and a reduction in the use of firewood and dirty fuel, albeit not sufficient to yield significant impacts.

4.5.2 Impact of the RLPGPP on Poverty

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 (4) of Table 4.5 report the estimation results by using the DID methodology after matching. 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. (2020), 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 theoretical 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. Furthermore, to check whether the program implementation led to a significant increase in infrastructure, we use the number of refill stations as an outcome variable via a matching-DID approach. The results are shown in column (1) of Table 4.5. 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) and (5) in Table 4.5 report the impact of the number of refill stations on poverty reduction. We include the change in the number of LPG refill stations (Δ Refill 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% (3.4%). 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 results confirm the findings of Kimemia and Annegarn (2016), who found that in South Africa, jobs and economic opportunities became available in beneficiary areas, and consequently, led to a reduction in poverty.

Table 4.5: Effects on number of refill stations and poverty reduction

	Δ Refill Stations (1)	Δ Poor (2)	Δ Poor (3)	Δ Very poor (4)	Δ Very poor (5)
DID	0.531* (0.276)	-0.128** (0.057)	-0.121** (0.054)	-0.102** (0.041)	-0.097** (0.040)
Δ Refill Stations			-0.058*** (0.018)		-0.034** (0.014)
Constant	0.490** (0.195)	0.161*** (0.040)	0.213*** (0.042)	0.118*** (0.029)	0.148*** (0.031)
Observations	98	98	98	98	98
R-squared	0.037	0.050	0.140	0.060	0.117

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.

4.5.2.1 Results from IV estimation

Table 4.6: Effects on poverty reduction (OLS and LIML IV)

Dependent variable	Δ Poor		Δ Very poor	
	(1)	(2)	(3)	(4)
DID	0.081* (0.044)	-0.350 (0.446)	0.044 (0.030)	-0.134 (0.263)
Constant	0.298*** (0.025)	-0.012 (0.131)	0.113*** (0.016)	-0.073 (0.077)
	OLS	IV	OLS	IV
Observations	163	161	163	161

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

From the IV results shown in Table 4.6 (columns (2) and (4)), we observe no statistically significant impact of the RLPGPP on poverty reduction in rural districts. As mentioned

in the methodology section, the IV turned out to be weak and could explain why it was unable to determine the significant impacts revealed by the DID approach after matching in the case of the RLPGPP's impacts on poverty reduction. These considerations partly justify the use of the matching-DID technique for our main analysis.

4.5.2.2 Impact on employment

As additional analyses, we test the program's impact on employment. We use the approach of matching with DID as before, and the results are shown in Table 4.7. While there is no evidence to suggest that the program by itself yielded significant effects on employment in the district, the change in refill stations led to significant positive effects on employment, confirming the earlier results. Employment in a district is the result of several factors, possibly including other employment-oriented interventions whose treated districts may differ from those under this fuel choice intervention. Consequently, the treatment in this intervention cannot be credited directly for any changes in employment; however, the refill station variable makes a significant contribution to the increase in employment in treated districts. In summary, our findings suggest that the program significantly increased refill stations in treated districts, which, in turn, contributed significantly to increasing employment, and consequently, reducing poverty in those districts.

Table 4.7: Effects on employment

Variable	(1) Δ Employment	(2) Δ Employment
DID	0.009 (0.030)	-0.006 (0.030)
Δ Refill Stations		0.028*** (0.011)
Constant	-0.088*** (0.021)	-0.102*** (0.021)
Observations	98	98
R-squared	0.001	0.070

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

4.6 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 spill-over 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 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.

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.

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APPENDIX 4A: Balancing test results for Δ LPG use and Δ Firewood use models

		Mean		%	% reduction	t	p>t
Variable		Treated	Control				
				bias	bias		
Ecological	Unmatched	2.327	2.124	29.4		1.78	0.077
zone	Matched	2.327	2.327	0	100	0.00	1.000
Firewood	Unmatched	0.8	0.774	12.6		0.71	0.476
use	Matched	0.8	0.807	-3.5	72.3	-0.19	0.851

APPENDIX 4B: Balancing test results for Δ Dirty fuel use model

		Mean		%	% reduction	t	p>t
Variable		Treated	Control				
				bias	bias		
Ecological	Unmatched	2.327	2.124	29.4		1.78	0.077
zone	Matched	2.327	2.347	-3	89.9	-0.14	0.892
Dirty fuel	Unmatched	0.942	0.941	0.9		0.05	0.957
use	Matched	0.942	0.953	-10.1	-1016.4	-0.54	0.589

CHAPTER FIVE

Impact of liquefied petroleum gas promotion program in Ghana: The role of distance to refill

Abstract

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

Keywords

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

5.1. Introduction

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

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

In Ghana, the Rural LPG Promotion Program (RLPGPP) was rolled out in 2013 and continued for four years. The RLPGPP aimed to make LPG the primary cooking fuel for rural residents. The RLPGPP distributed free LPG cylinders, cookstoves, and accessories to rural households as they transitioned from firewood and charcoal to LPG, thus removing the initial cost barrier. According to the Ghana Living Standards Survey (GLSS VII) collected in 2017, LPG is the primary cooking fuel for 18.4% of households.¹⁶ While the use of LPG among urban households is as high as 34.9%, only 6% of rural households use LPG as their primary cooking fuel. Ghana's 2012 Sustainable Energy for All Action Plan targeted a 50% household LPG access rate by 2020 (Energy Commission, 2012), and programs such as the RLPGPP were part of interventions to achieve the target. Documents provided by Ghana's Ministry of Energy, the implementing agency for the

¹⁶ It slightly increased from the share of 16.9% in 2013 (GLSS VI). The proportions of Ghana households that use firewood and charcoal as primary cooking fuel stand 46.5% and 28.2%, respectively.

RLPGPP, show that from 2013 to 2017, 149,500 cylinders and 118,360 cookstoves with accessories were distributed in a third of districts nationwide. RLPGPP has since been discontinued, but the effect of the program remains to be measured. Concerning other LPG programs, the government of Ghana in 2017 proposed replacing the current LPG distribution system with a new one known as the LPG cylinder recirculation model. However, this program has not been implemented, and the existing distribution system has not been replaced.

This study contributes to the literature in three ways. First, we focus on the distance to refill stations as a key to promoting LPG usage. While researchers evaluated the impact of clean cooking programs (Calzada and Sanz, 2018; Kimemia and Annegarn, 2016; Andadari, 2014), they did not consider the impact of distance to obtain LPG on use. Because access to refill stations represents a considerable cost for rural households, it is crucial to examine their effect on fuel usage. Second, this study examines the treatment effect of a clean cooking intervention that reduces only the initial cost of use by providing free equipment. Although earlier studies have conducted similar impact evaluations in other countries, the interventions are mostly subsidies or contain a price support mechanism. For example, Calzada and Sanz (2018) explored Peru's program, which offers monthly vouchers to treated households to be exchanged for LPG. Kimemia and Annegarn (2016) examined South Africa's policy to control the maximum retail price of LPG. In both cases, the interventions included a subsidy or a price support mechanism, which continued over a long period, whereas the Ghanaian program provided one-time free LPG equipment. It is crucial to ascertain whether this marked difference relative to price leads to differences in the treatment effects.

Initial setup costs are known to limit LPG usage, and hence the removal of these costs could represent a significant push towards a transition to clean cooking fuel. On the other hand, since affordability has been noted in the literature to be significantly related to LPG use (Karimu et al., 2016), a policy with continuous subsidies and price support systems is expected to have a good response from households. The only previous evaluations of the RLPGPP in Ghana used a descriptive approach (Asante et al., 2018) or evaluated spillover effects at the district level (Adjei-Mantey and Takeuchi, 2019). This study differs from these studies in that it collects original survey data and uses micro-econometric analysis at the household level. Third, this study investigates the willingness to pay (WTP) for an improved LPG delivery system. By using the stated preference technique, studies such as Chindarkar et al. (2021), Zahno et al. (2020), and Jeuland et al. (2015)

examined WTP to use LPG and improved cookstoves. Our study complements the above literature by focusing on the WTP for the delivery system as a practical and operational LPG use dimension.

The remainder of this paper is structured as follows: Section 5.2 reviews the relevant literature, while Section 5.3 describes the data and the strategies to collect them. Section 5.4 explains the methodology adopted for analyzing the treatment effect, and the results are discussed in section 5.5. Section 5.6 explores the WTP for LPG delivery services and their determinants, and Section 5.7 concludes the study.

5.2. Literature Review

Several studies have investigated the impact of clean-cooking interventions. These intervention schemes take various forms across different countries. Calzada and Sanz (2018) evaluated Peru's program to substitute LPG for traditional stoves among low-income households. The beneficiaries received monthly discount vouchers under the program, which amounted to half the cost of an LPG cylinder. By applying matching techniques, the researchers observed that beneficiary households used LPG to cook 33%–38% more than non-beneficiaries. Additionally, they found no evidence that the use of LPG reduced respiratory problems in beneficiary households.

In contrast, the program might reduce the exposure of children to water-related diseases by increasing the use of LPG stoves for boiling water. Pollard et al. (2018) evaluated the same program in Peru using data from a different province. In addition to reporting a greater likelihood of LPG usage among beneficiaries, thus confirming Calzada and Sanz's (2018) findings, the study finds that kitchen concentrations of PM_{2.5}, were lower for program beneficiaries, hence lower exposure to household air pollution among this group.

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

The Indonesian government embarked on a fuel conversion program that involved removing subsidies on kerosene and reallocating them to LPG. Imelda (2020) evaluated the impact of the program on fuel choice and infant mortality. Overall, she found that the program increased the number of households that used LPG as primary fuel by 350%–900% while reducing households that relied on kerosene as primary fuel by 75%–146%. The study also found that the program reduced infant mortality by a conservative estimate of 25%, possibly through the channel of improved indoor air quality associated with LPG use. Andadari et al. (2014) also found that LPG consumption increased after the program, with a significant shift from kerosene usage across large sections of the population. This shift was also due to the increased prices of kerosene because of subsidy removal. The study found that the program helped alleviate extreme energy poverty in Indonesia by substantially increasing LPG usage. Both evaluations of the Indonesian fuel conversion program confirmed the effectiveness of the program in promoting LPG use.

Few studies have been conducted on Ghana's RLPGPP. Asante et al. (2018) examined the program's effect in the Nkoranza North District of Ghana and observed that LPG usage was low among beneficiary households. After 18 months of program implementation, less than 10% of respondents still used LPG, and all respondents used firewood or charcoal as their primary fuel. Further analysis showed that the program did not yield significant changes in personal exposure to carbon monoxide. Adjei-Mantey and Takeuchi (2019) examined the program's spillover effects at the district level using nationwide survey data. The study found no evidence of the program's significant impact in choosing LPG over fuelwood in beneficiary districts. The study, however, found that the RLPGG contributed to poverty alleviation in beneficiary districts. The potential channel was through the increased number of LPG refill stations established in beneficiary districts throughout the program's implementation.

In contrast to studies revealing the effectiveness of clean cooking interventions, studies in Ghana have not supported this narrative. The limitations of these studies can be summarized as follows. First, Asante et al. (2018) did not compare beneficiaries to non-beneficiary households to measure program impact. That study focused on the reach, effectiveness, adoption, implementation, and maintenance (REAIM) framework and was based solely on beneficiary households. This study contributes by comparing beneficiaries to non-beneficiaries under a quantitative framework to measure impact. Second, Adjei-Mantey and Takeuchi (2019) examined the program's spillover

impacts at the district level, even though the program targeted selected households. Thus, there is a possibility that fuel choice changes at the household level were not large enough to impact the district level significantly. Therefore, an evaluation at the household level is necessary to ascertain the results in more detail. Finally, the other countries' programs used price support for consumers, such as subsidies and discount vouchers. Instead, Ghana's RLPGPP reduced the initial cost of introduction but did not include support for continuous usage, thereby not protecting consumers from high fuel costs. Because the downstream petroleum sector has been deregulated in Ghana, prices are not controlled and fluctuate due to market conditions. Examining the impact under this condition allows us to enrich the literature concerning program implementation.

Other clean cooking interventions involved the use of improved cookstoves (ICSs). ICSs require a lower amount of biomass fuel than traditional cookstoves and hence emit fewer pollutants. Empirical studies on ICSs use have shown that with the right level of accompanying moderating policies, these interventions often led to increased adoption of cookstoves to improve clean cooking (Levine et al., 2018; Bonan et al., 2017; Bensch and Peters, 2015; Miller and Mobarak, 2014). Although there is a common feature with the current study, the evaluation of LPG intervention has a particular implication for understanding the policy that substantially reduces indoor air pollution.

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

In contrast to these studies, Beltramo et al. (2015) found that marketing information on the health-improving features of ICSs did not increase WTP for fuel-efficient cookstoves in Uganda. However, they also found that WTP was 40% higher when the payment due was over four weeks than within a week. The result highlighted the importance of liquidity or affordability barriers that households face when adopting ICSs. Similarly, Jeuland et al. (2015) used a discrete choice experiment to elicit WTP for improved cookstoves in India. They found that WTP was highest for

the smoke-reducing attribute of the improved cookstoves, followed by the convenience of cookstoves and the reduction in fuel requirement. These findings suggested that households had a higher WTP to reduce smoke emissions, and LPG fit well into this cooking mode. While these studies are an important precedent of investigations on household preferences for clean cooking, they did not consider the WTP for a system that assures a constant supply of these fuels. Our study fills this gap by examining the WTP for LPG delivery to reduce access to further adoption barriers.

5.3. Data

5.3.1 Data Collection

We collected data by conducting face-to-face interviews in the Ga South¹⁷ and Ada West districts of Ghana. The important factor in selecting study areas was the availability of the list of beneficiary households of RLPGPP to identify treatment groups in the districts. Among the few districts for which Ghana's Ministry of Energy provided the list of households that benefitted from the program, the Ga South and Ada West districts' lists were complete, as they contained the contact information of each household. In both districts, 1,000 households benefitted from the RLPGPP, which was implemented in these districts in 2017.

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

We used electoral areas within the districts as enumeration areas (EAs) for the survey. In Ghana, electoral areas are geographical demarcations in each district for political administration and decentralized governance. The distribution of LPG equipment under the RLPGPP was done at the electoral area level, with lists of beneficiaries available for each district's electoral areas. Ada West has 15 electoral areas, and Ga South has 23 electoral areas. Considering the geographical balance,

¹⁷ Ga South is officially identified as a municipality. However, we refer to both Ga South and Ada West as districts throughout this study for simplicity.

we sampled seven electoral areas in Ada West and 13 electoral areas from Ga South as EAs for the survey¹⁸. Following stratification of households on an electoral area basis, random sampling was employed to sample treated households using the beneficiary list information. We used a snowball sampling strategy to complement simple random sampling to select non-beneficiary respondents within the same EA to serve as a control group. The number of candidates for respondents in each EA was proportional to the number of households that benefited from the program in that EA. When candidates were unavailable due to relocation from the community, travel, non-cooperation, or unreachability, we replaced them with other households from the same EA.

The field survey was conducted using computer-assisted personal interviews (CAPI) from August 3rd to 31st, 2020. The exercise began with a training program for survey enumerators, after which a pilot survey was conducted to check whether the questionnaires were suitable and understandable to the respondents. The pilot survey also provided enumerators an opportunity to practice with the survey instrument ahead of the main exercise. After revisions of the instrument based on the pilot exercise's feedback, the main field survey was conducted by 14 enumerators. The total number of successful interviews was 904, of which 448 were conducted in Ada West and 456 in Ga South.

5.3.2 Data Description

Table 5.1 presents summary statistics of the data. The data showed that 45% of the sample benefitted from RLPGPP. As mentioned in the above section, the percentage is higher than the actual share of beneficiaries in each district, approximately 8.5% in Ada West and 1% in Ga South. The proportion of households that used LPG as their main fuel stood at 43%, while about 40% used LPG comparably more than other fuels in the seven days preceding the interview day. LPG usage rate is calculated as frequency of LPG usage in a day as a ratio of frequency of cooking in a day.¹⁹ The mean LPG usage rate was 52%; on average, households used LPG once out of every two cooking times. Regarding occupation, 28% of the sample worked in the agricultural sector. On average, a round-trip to the nearest LPG refill station took 42 minutes (travel time only).

¹⁸ A list of sampled EAs is provided in Appendix A

¹⁹ For example, if a household cooks three times a day and uses LPG two times a day, this household's LPG usage rate becomes 0.67.

Table 5.1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Treatment	904	0.4524	0.4980	0	1
Distance to refill station (mins)	836	41.617	29.338	1	240
LPG is main fuel	904	0.4336	0.4958	0	1
LPG in past 7 days	904	0.3971	0.4896	0	1
LPG usage rate	866	0.5180	0.4459	0	1
Education (years)	904	7.3982	4.5010	0	16
Occupation (1 = agriculture)	904	0.2810	0.4497	0	1
Access to information	904	0.8440	0.3630	0	1
Access to financial services	904	0.6560	0.4753	0	1
Rural	904	0.7743	0.4183	0	1
Risk averse	904	0.7721	0.4197	0	1
District (1 = Ga South)	904	0.5044	0.5003	0	1
WTP (cedis) *	904	6.9735	3.6936	2	20
Household income (cedis)	904	1781.25	1697.72	0	22600

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

5.4. Empirical Methodology – LPG Usage

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

$$\Pr_i(LPG) = \Pr(U_{i,LPG} > U_{i,others}). \quad (5.1)$$

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

$$\Pr_i(LPG) = \beta_0 + \beta_1 T_i + \beta_2 D_i + \beta_3 A_i + \beta_4 X_i + \varepsilon_i, \quad (5.2)$$

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

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

The above approach assumes that the Ministry of Energy randomly chose the beneficiaries of the RLPGPP. In the actual implementation of the program, there were no criteria for household selection in beneficiary districts. The field data showed that some beneficiaries owned LPG

equipment before the program implementation and still benefitted from this program²⁰. This affirmed the randomness in the beneficiary selection since all households stood the chance of benefiting from the program regardless of whether they owned LPG or not. Furthermore, given that households had nothing to lose if they opted out of the program, a randomly selected beneficiary household's chances to self-select themselves out of the program were meager. On this basis, the treatment was deemed exogenously determined; hence, the chosen approach is appropriate for estimating treatment effects. This notwithstanding, we considered potential biases in selecting households in some areas beyond the supervising authority's control. As an additional analysis, we used matching techniques to mitigate against potential bias from the possibility that some beneficiary households may not have been selected randomly. Based on the baseline covariates that were likely to affect the treatment selection, beneficiary households were matched with non-beneficiary households. Because treated and control households were matched on common characteristics, any differences in the outcome variables between treated and control households could be attributed to the treatment.

We used Mahalanobis distance matching (MDM) and propensity score matching (PSM) estimators. For every treated observation, the MDM calculates the distance between its covariates and those of control households and matches treated households with the control households with the shortest distance in covariates. On the other hand, PSM allows us to estimate the probability of a household being treated (the so-called propensity score) based on its characteristics (Rosenbaum and Rubin, 1983). Each treated household is then matched with a control household that had similar propensity scores. In both cases, the matching was done on the following covariates: occupation, distance to the nearest refill station, access to financial services, access to information, education, location, and income.²¹

²⁰ Among the sample of treated households, 27.6% owned LPG before benefiting from the RLPGPP. We conducted a sub-sample analysis that excludes this group of treated households. The results are discussed in Section 5.

²¹ Tables in Appendix B summarize the balancing properties of covariates for both matching estimators.

5.5. Results and Discussion

5.5.1 Treatment effect and determinants of LPG usage

Columns (1-3) of Table 5.2 show the probit estimation results on the factors that influenced the choice of LPG as the primary cooking fuel for the household. Columns (4-5) present the results from the matching estimators.

Table 5.2: Main results: dependent variable = LPG is the main fuel (LPG = 1; otherwise, 0)

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Probit	Probit	Probit	MDM	PSM
Treatment	0.262*** (0.032)	0.218*** (0.034)	0.235*** (0.036)	0.223*** (0.040)	0.203*** (0.044)
Distance to refill		-0.004*** (0.001)	-0.002*** (0.001)		
Other control variables	No	No	Yes	-	-
District effects	Yes	Yes	Yes	-	-
Observations	904	836	836	814	814

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

The results shown in Table 5.2 indicate a positive and statistically significant effect of the program. Treated households were more likely to choose LPG as their primary fuel by 23.5% compared to non-treated households. This finding suggests that the program contributed to increased LPG usage among the households that benefited from the program. This result is consistent with those of other studies on clean cooking interventions. The size of the treatment effect found in our study was smaller than that found in the Peruvian study by Calzada and Sanz (2018). This difference might be a result of the different features of the interventions. Beneficiaries in Peru receive a monthly voucher for LPG. However, this continuous LPG subsidy is not present in the RLPGPP in Ghana, and could lower the treatment effect. Our findings were inconsistent with those of Adjei-Mantey and Takeuchi (2019) [see: chapter 4], who found no significant increase in LPG use. This result can be attributed to the differences in the study's focus. Adjei-Mantey and Takeuchi (2019) examined the district-level impact using data from official statistical surveys and found that the program did not yield significant spillover effects. In contrast, the

current study examined the impact at the household level, which is the actual unit for treatment. The closer focus of the analysis in this study could account for the difference in results from the previous study. The results from the MDM and PSM, shown in columns (4) and (5), confirmed the positive impact of the program on LPG use, and the magnitude of the effect is consistent. Treated households increase LPG use as their main fuel by 20% to 22% compared to non-treated households. The coefficients' sizes were comparable to the estimates from the main results, as shown in (2) and (3).

The coefficient for the distance to the nearest LPG refill station was negative and statistically significant, suggesting that LPG usage decreases with distance. We found that for every minute increase in the travel time to access a refill station, the probability of choosing LPG as the main fuel reduced by 0.2%. The distance to a refill station represents the monetary and time costs for households commuting. Thus, a longer distance reduced the choice of LPG as the primary cooking fuel. The result highlights the importance of providing an LPG distribution service that refills cylinders more conveniently with less time and travel costs. Adjei-Mantey and Takeuchi (2020) discussed that accessibility of refill stations is a potential risk that households face when switching to LPG use. Dendup and Arimura (2019) also noted that distance to the nearest market negatively affected the choice of LPG, while Dalaba et al. (2018) found no significant association between distance to a refill station and LPG ownership in northern Ghana.

To check the robustness of our choice of outcome indicator, we replaced LPG as the primary fuel with other dependent variables and compared the effect of treatment. Table 5.3 summarizes the results of the regressions with the alternative dependent variables. The marginal effects on the recent LPG usage (LPG in the past 7 days) and the LPG usage rate (ratio of LPG use to the total number of times of cooking in a day) are reported in columns (2) and (3), along with the main result (1), which is already indicated in column (3) of Table 5.2. Model (2) was estimated using probit and (3) by fractional probit regression.

Table 5.3: Other dependent variables

	(1)	(2)	(3)
	LPG is main fuel	LPG in past 7 days	LPG usage rate
VARIABLES	Probit	Probit	Fractional Probit
Treatment	0.235*** (0.036)	0.195*** (0.036)	0.333*** (0.029)
Distance to refill	-0.002*** (0.001)	-0.003*** (0.001)	-0.004*** (0.001)
Agricultural worker	-0.085* (0.044)	0.017 (0.044)	-0.023 (0.039)
Income	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)
Education	0.030*** (0.004)	0.029*** (0.004)	0.020*** (0.003)
Risk averse	-0.066 (0.046)	-0.122*** (0.045)	-0.092** (0.037)
Rural	-0.282*** (0.051)	-0.279*** (0.052)	-0.287*** (0.042)
District effects	Yes	Yes	Yes
Observations	836	836	798

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

The estimated coefficients in Table 5.3 are positive and statistically significant, suggesting a positive impact of treatment on LPG choice. The chances of using LPG more than other fuels and usage rate of LPG were higher for treated households than for others by about 20% and 33%, respectively. These results are consistent with the main results from Table 5.2 that suggested a positive impact of the program on LPG use as the primary fuel. The significant effect of the distance to the nearest LPG refill station was also confirmed. An additional minute to a refill station reduces the probability of using LPG more than other fuels and LPG usage frequency by 0.3% and 0.4%, respectively.

The estimated coefficients for the other control variables are also in line with expectations. Agricultural workers chose LPG as their primary cooking fuel at an 8.5% lower likelihood than non-agricultural workers in model (1). This result is consistent with the findings of Saksena et al.

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

Table 5.4 presents results that exclude households that owned LPG before benefitting from the RLPGPP. The results can be regarded as a lower bound estimate because it measures the program's impact on treated households who became first-time owners of LPG equipment under the program without considering the program's impact on other beneficiary households. A positive and statistically significant impact of the program is observed among the sub-sample. Compared to the main results, the estimated treatment effects on LPG usage were lower. This is because households who own multiple LPG equipment will use LPG even more than households with single LPG equipment. While one cylinder is in use, another cylinder could be filled with LPG and be ready to substitute should the active cylinder run out of gas. Households with only one cylinder do not have this advantage. Therefore, if they run out of gas during cooking or when it is inconvenient to commute to refill their cylinders, they are likely to use firewood or charcoal as temporal substitutes.

Table 5.4: Exclusion of households that owned LPG before treatment

	(1)	(2)	(3)
VARIABLES	LPG is main fuel	LPG in past 7 days	LPG usage rate
	Probit	Probit	Fractional probit
Treatment	0.162*** (0.039)	0.118*** (0.039)	0.314*** (0.032)
Distance to refill	-0.002*** (0.001)	-0.002*** (0.001)	-0.004*** (0.001)
Agricultural worker	-0.063 (0.045)	0.021 (0.045)	-0.009 (0.042)
Income	0.004*** (0.001)	0.003** (0.001)	0.005*** (0.001)
Education	0.029*** (0.005)	0.028*** (0.004)	0.022*** (0.004)
Risk averse	-0.053 (0.049)	-0.097** (0.049)	-0.120*** (0.041)
Rural	-0.289*** (0.057)	-0.276*** (0.057)	-0.298*** (0.048)
District effects	Yes	Yes	Yes
Observations	723	724	692

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

5.5.2 Heterogeneity analyses

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

Table 5.5: Heterogeneous effects; probability of choosing LPG as household's main cooking fuel

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Shorter distance	Longer distance	Agricultural worker	Non-agricultural worker	Lower income	Higher income
Treatment	0.211*** (0.055)	0.250*** (0.047)	0.073 (0.066)	0.316*** (0.042)	0.308*** (0.047)	0.154*** (0.050)
Distance to refill			-0.002* (0.001)	-0.002** (0.001)	-0.002*** (0.001)	-0.002 (0.001)
Agricultural worker	-0.115* (0.067)	-0.055 (0.055)			-0.089* (0.054)	-0.077 (0.064)
Income	0.007*** (0.002)	0.002* (0.001)	0.002 (0.002)	0.005*** (0.002)		
Education	0.034*** (0.007)	0.024*** (0.006)	0.018** (0.008)	0.036*** (0.005)	0.026*** (0.006)	0.029*** (0.006)
Risk averse	-0.063 (0.074)	-0.088 (0.057)	-0.175* (0.099)	-0.016 (0.053)	-0.018 (0.065)	-0.077 (0.058)
Rural	-0.270*** (0.066)	-0.312*** (0.087)	0.011 (0.152)	-0.289*** (0.058)	-0.161* (0.091)	-0.295*** (0.065)
District effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	384	452	227	609	404	432

Note: Standard errors are shown in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5.5 summarizes the results. Models (1) and (2) show that the treatment had a slightly higher effect on households who lived farther from refill stations. The result suggests that the intervention's impact was more substantial for families living long distances from a refill station and felt inconvenienced using LPG. The importance of distance to access a refill station is crucial in households' decisions to use LPG and confirms the findings in earlier sections. In models (3) and (4), the treatment effect is not significant among agricultural workers but is significant among non-agricultural workers. Among non-agricultural workers, treated households were 32% more likely to use LPG as their main fuel than non-treated households. For agricultural workers, treated households were not likely to use LPG significantly more than non-treated households. The treatment of the program for this subgroup did not matter for usage. As previously mentioned, the abundant supply of wood fuel and agricultural waste for agricultural workers provides a strong disincentive to use LPG. Saksena et al. (2018) also found that Vietnam's agricultural households had a positive and significant use of wood fuel. In models (5) and (6), we saw that the treatment

effect is twice as potent in the lower-income group than in the higher-income group. These results agree with those of Calzada and Sanz (2018) and Troncoso and da Silva (2017), who found similar conclusions in their study of cooking fuel interventions. This result suggests that a minimum level of income may be sufficient to induce LPG usage.

5.6. Willingness to pay for LPG delivery

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

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

Following this explanation, we asked the maximum amount per delivery (aside from the gas price) the respondent was willing to pay as a choice from the list of fee options. The listed fees varied from 0 to more than ₵20 and increased by ₵2. Box plots were used to analyze the data and they

show the distribution across different subgroups. In addition, we examined the factors that are likely to influence households' WTP by specifying the following model:

$$\text{WTP} = \alpha_0 + \alpha_1 T_i + \alpha_2 D_i + \alpha_3 A_i + \alpha_4 X_i + \varepsilon_i \quad (5.3)$$

where α_i are coefficients to be estimated, and T , D , A , and X are as previously explained in (5.2). Ordinary least squares (OLS) was used to estimate equation 5.3.

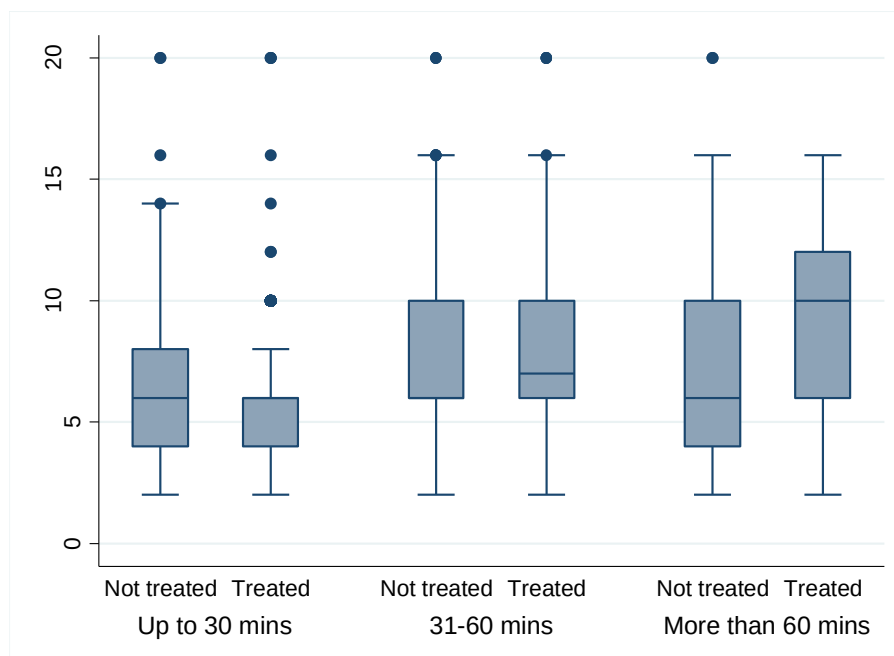


Figure 5.1: Distribution of willingness to pay

Table 5.6: Determinants of willingness to pay (WTP) for new LPG distribution system

Dependent variable: WTP amount (in Ghana cedis)			
	(1)	(2)	(3)
VARIABLES	Full sample	Treated	Not treated
Treatment	0.101 (0.240)		
Distance to refill	0.040*** (0.004)	0.047*** (0.006)	0.030*** (0.007)
Agricultural worker	0.046	0.140	-0.146

	(0.286)	(0.395)	(0.421)
Income	0.004	0.004	0.004
	(0.007)	(0.008)	(0.013)
Education	0.079***	0.132***	0.029
	(0.027)	(0.039)	(0.038)
Risk averse	0.283	0.197	0.359
	(0.294)	(0.404)	(0.428)
Rural	-0.324	-0.560	-0.008
	(0.351)	(0.485)	(0.509)
Constant	5.228***	5.021***	5.570***
	(0.521)	(0.710)	(0.762)
District effect	Yes	Yes	Yes
Observations	837	408	429
R-squared	0.132	0.214	0.066

Note: Standard errors are shown in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 5.1 shows the distribution of WTP across treatment groups and the distance to refill stations. There appeared to be no significant differences in WTP between the treatment and control groups. The mean WTP for treated and control groups were ₦7.01 and ₦6.94, respectively, while the total mean was ₦6.97 (\$1.20). This amount is about 22% of the average cost of refilling a 6 kg LPG cylinder at the time of the survey (₦31.14), which was the size of cylinders distributed under the RLPGPP. The distribution showed that households that live farthest from refill stations (more than 60 minutes round trip) had higher WTP than households that live closest to refill stations. The results aligned with expectations because households that live closer to refill stations are likely to incur lower money and time costs to travel to refill stations than households that lived farther.

Table 5.6 presents the results from OLS estimation on the drivers of WTP. Regression results from Table 5.6 confirmed that the treatment had no significant effect on households' WTP for the proposed distribution system. However, distance to the refill station was positive and significantly associated with WTP. An increase in the travel time by 10 minutes increases WTP by ₦0.4 (\$0.07) to access this service. Sub-sample analysis in columns (2) and (3) suggests that the effect of distance is stronger for treated households than for untreated households. Thus, the WTP of treated households was more sensitive than non-treated households. The results confirm the opportunity to implement the cylinder circulation model of LPG distribution, especially for communities located far from refill stations. Larsen et al. (2020) estimated that such a system has cost reduction

potential of about 28% for rural households in Ghana and could increase rural LPG consumption by about 37%. Education was also found to increase WTP, similar to the findings of Chindarkar et al. (2021) and Zahno et al. (2020) that exposure to health awareness increases WTP for LPG in India.

5.7. Effects of supply side features

This chapter further examined the impact of supply side characteristics on household use of LPG. Consider a refill station that offers additional services in addition to selling LPG. These additional services include but are not limited to sales of groceries, sale of LPG accessories, and repair of LPG cylinders and cookstoves. We investigated whether the presence of these additional services at the refill stations have any effects on household choice of LPG as primary fuel and frequency of LPG usage. Figure 5.2 shows that around half (52%) of the refill stations in the study areas offer additional services.

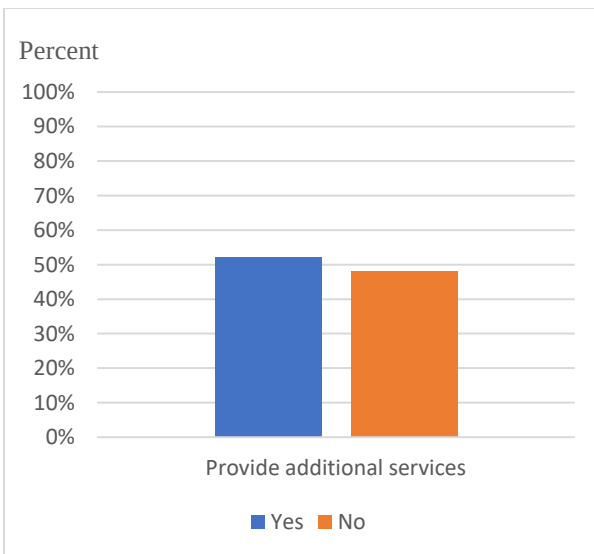


Figure 5.2. Provision of additional services at LPG refill stations

Table 5.7 reports the result of the analysis. Adding the variable on a supply side feature to the model specified in equation (2), we found that provision of additional services at refill stations is positively related to LPG use. While it is not significant in the model that explains the LPG

adoption as main cooking fuel, it is strongly significant in the model that uses the frequency of LPG use as the dependent variable.

Table 5.7. The role of additional service provision

	(1)	(2)
VARIABLES	LPG is main fuel	LPG usage rate
Additional services	0.068 (0.066)	0.193*** (0.058)
Treatment	0.227*** (0.039)	0.330*** (0.030)
Distance to refill	-0.003*** (0.001)	-0.004*** (0.001)
Other control variables	Yes	Yes
District effects	Yes	Yes
Observations	751	720

Note: Standard errors are shown in parentheses

*** p<0.01, ** p<0.05, * p<0.1

After controlling for distance to the station, households, for which the refill station closest offers multiple services, tend to have a 19.3% higher chance of using LPG more frequently than households where the nearest refill stations are single-service refill stations. We can interpret this result as indicating that the additional services act as ‘pull factors’ that attract households to the refill stations. It increases their frequency of LPG use as they have more reasons to visit the stations. For example, if a station sells groceries, a household could shop for groceries and refill their cylinders hence making a time saving in a single visit. For a household that uses a station with single purpose, the household must make a visit to the station to refill their LPG cylinder and a different visit to another location to purchase groceries. The time and money cost involved in this extra trip might be considered a burden, thereby reducing regular LPG use to avoid multiple trips.

5.8. Conclusions and Policy Implications

This study investigated the impact of the LPG promotion program in two districts of Ghana. We found that the program successfully increased the likelihood of choosing LPG as the household's primary cooking fuel, and the results were robust across different specifications. The distance to refill stations played a significant role in the decision to use LPG. Households that live far from refill stations were less disposed to use LPG because of the obvious inconvenience and costs of commuting to refill stations. These households also had a positive and significant association with WTP for the proposed LPG delivery. This distribution model is similar to the LPG cylinder recirculation model proposed by the government of Ghana. Furthermore, households who are likely to patronize LPG stations that provide additional services tend to use LPG more frequently as the additional service provision acts as a 'pull factor' that induce a household's visit to the refill station. It provides more opportunities to refill their LPG cylinders with little or no extra time and money cost incurred.

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

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Appendix 5A: Sampled EAs

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

Appendix 5B: Covariate balance summary

The tables below show the differences between the treated and control households before and after matching for both estimators. After matching, the differences were significantly reduced for all covariates in both the MDM and PSM. For example, a difference before matching of 0.186 between treated and control concerning access to information reduces to an absolute difference of 0.008 after matching. These results show that matching makes the treated and control households more similar than the absence of matching.

Table 5B1: Balance before and after the matching

(A) Mahalanobis distance matching (MDM).

VARIABLES	Standardized differences		Variance ratio	
	Unmatched	Matched	Unmatched	Matched
Access to information	0.1860	-0.0079	0.6756	1.0204
Access to financial services	0.2085	-0.0165	0.8581	1.0166
Distance to refill station	-0.1612	0	1.0127	1.0417
Agricultural worker	0.1021	0.0162	1.1107	1.0150
Education	0.0889	0.0229	0.8533	1.0505
Income	0.1408	0.0600	2.3854	1.1866
Rural	-0.0076	0	1.0093	1

(B) Propensity score matching (PSM)

VARIABLES	Standardized differences		Variance ratio	
	Unmatched	Matched	Unmatched	Matched
Access to information	0.1860	0.0079	0.6756	0.9805
Access to financial services	0.2085	-0.0554	0.8581	1.0600
Distance to refill station	-0.1612	0.0360	1.0127	1.1227
Agricultural worker	0.1021	0.0824	1.1107	1.0861
Education	0.0889	0.0236	0.8533	0.8917
Income	0.1408	0.0774	2.3854	1.6423
Rural	-0.0076	-0.0404	1.0093	1.0513

CHAPTER SIX

Conclusion

The crucial role of energy in the development agenda of any nation cannot be overemphasized. Despite the volume of research that have been done previously, current energy use statistics particularly in developing countries suggest a need for further research. New insights and evidence form the bases for policy formulation in such developing countries. Chapters in this thesis so far have attempted contributing to the literature and policy formulation through analyses on household cooking energy in Ghana. The thesis investigated how the use of dirty cooking fuels and the consequent exposure to household air pollution *in utero* affected child health in Ghana. Furthermore, the effect of behavioral factors such as risk aversion on choice of clean cooking fuel was examined. Finally, the thesis conducted an impact evaluation of a government sponsored clean cooking fuel intervention in Ghana by measuring direct impacts at the household level as well as spillover effects of the program on its objectives and unintended impacts at the district level.

Based on findings from Chapter 2, we conclude that children born to households in districts that use dirty fuel predominantly are shorter on average after birth. Disaggregated analysis showed that boys tend to suffer larger negative impact from *in utero* exposure to household air pollution on their height for age than girls. Therefore, by continuing the use of dirty fuel and thus exposing expectant mothers to household air pollution, households suffer a negative health effect and hence, the benefit of cleaner cooking fuel is high particularly where pregnant women are present in the household.

Findings from Chapter 3 suggest a link between risk aversion and the choice of LPG as primary cooking fuel. For people who are risk averse, factors such as unavailability of LPG for purchase reduces the probability of choosing LPG as a primary cooking fuel. By mitigating the risks associated with LPG use in Ghana, it is possible to reduce the negative impact of risk aversion on LPG use. It was further found that risk aversion affects other household behaviors such as contraceptive use, adoption of e-commerce and probability of changing jobs. The results suggest that the relationship between risk aversion and clean cooking fuel choice was a valid relationship rather than a spurious one.

Chapters 4 and 5 both examined the impact of the Rural LPG Promotion Program (RLPGPP), a government led intervention for the transition to clean cooking fuel. Chapter 4 concludes that the RLPGPP may not have had significant spillover impact on fuel choice in treated districts. There is evidence, however, that the RLPGPP has had significant impact on poverty reduction in treated districts which is consistent across different robustness checks. The likely channel of impact on poverty is the significant increase in LPG refill stations in treated districts. The stations provide more job opportunities and other avenues to enhance livelihoods. In contrast, Chapter 5 suggests that the RLPGPP has had a positive impact on LPG choice among households treated by the program. Treated households choose LPG as their primary fuel 23% more than untreated households. Additionally, the frequency of LPG use is positively and significantly affected by the treatment. Treated households have a higher LPG usage rate compared to non-treated households. The distance to refill stations is a significant negative predictor of the choice of LPG among households. Households who live farther from refill stations are less likely to choose LPG as their primary cooking fuel. There are significant heterogeneities in the impact of the program. It has no impact on fuel choice by agricultural workers but significant impact among non-agricultural workers. Furthermore, lower income households respond better to the program than higher income households. An investigation of households' willingness to pay showed that there is stated preference for an improved LPG distribution model that makes access to the fuel easier and more convenient. Households are willing to pay for home delivery of LPG without having to commute to gain access to the fuel. Willingness to pay increases with the distance to refill stations; that is, households that live farther from refill stations are willing to pay more for the proposed distribution model while for households within similar distances of refill stations treated households tend to have a higher willingness to pay for the service than non-treated households.

In Chapter 5, we also found that the provision of additional services at LPG refill stations increases the LPG usage rate but has no significant effect on the decision to choose LPG as primary fuel. In other words, the decision to choose LPG is independent of the number of services offered at refill stations. However, once the decision has been made, the frequency of LPG use in the household depends on additional services offered at refill stations. This is because households can perform multiple household tasks including refilling LPG cylinders with minimum trips to the stations thereby saving on time and financial costs of multiple trips to perform different household tasks. For example, for a refill station that sells groceries, households that visit the station to refill

their LPG cylinder can shop for household grocery needs simultaneously thus eliminating the need for another trip to the shopping center to purchase groceries.

Based on the above findings, this thesis recommends that the government of Ghana and other developing countries with similar energy use features ought to embark on several policies including clean cooking interventions with different programs for different population sub-groups. For example, agricultural workers require different interventions to promote clean cooking fuel use given their unique situation and abundance of wood resources available to them. Additionally, policies to make LPG easily available and accessible will be crucial not only towards mitigating the negative effects of risk aversion on LPG choice but also in promoting LPG use even after the implementation of intervention programs. For such intervention programs to achieve its objectives and for the effect to spill over into the larger districts, there ought to be corresponding infrastructure plans to accompany any such interventions. We further recommend the implementation of the cylinder recirculation model of LPG distribution beginning in communities without LPG refill stations in proximity. Lastly, households are encouraged to take advantage of government programs and support to switch to clean cooking fuel as they stand to suffer direct negative impacts from persistent dirty fuel use.