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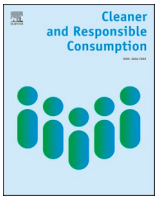

Consumption of clean and dirty cooking fuels in ghanaian households: The role of financial inclusion

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ABSTRACT

Home cooking is considered an important activity which promotes healthier lives, sustenance, and binds families and people together. Despite the benefits of home cooking, it is the leading source of household air pollution and its associated health risks particularly for developing countries including Ghana. The role of financial inclusion in facilitating the achievement of the Sustainable Development Goals (SDGs) of the United Nations is explored in this study for clean cooking technologies (i.e., SDG 7). The proposed study is based on three datasets from the Ghana Statistical Service (GSS), comprising of Ghana Living Standard Survey (GLSS) round 6, round 7 and the pooled form. Using distance to the nearest financial institution as instrument, the study employed probit two-stage least squares to investigate the heterogenous impacts of financial inclusion on household cooking fuels in Ghana. The findings show that financial inclusion increases the consumption of clean cooking fuel but reduces dirty fuels such as firewood, charcoal, kerosene etc. Female-headed households were found to be more impacted by financial inclusion over time than their male counterparts. The results also showed that financially included rural households reduced their consumption of dirty cooking fuels than their urban counterparts. These findings have important policy implications.

1. Introduction

Household air pollution has been of concern globally due to its devastating impacts on health and climate change. It is now considered among the top environmentally health risk factors as noted by the World Health Organization (WHO, 2018a). The impacts of household air pollution are more prominent among the poorest in the low- and middle-income countries who depend mainly on biomass (i.e wood, charcoal, crop wastes and animal dung) for cooking and heating purposes (WHO, 2018a). According to WHO (2021a), women and children are more exposed to the health burden of polluting cooking fuels since they are responsible for collecting firewood and spending more time at home. Exposure to smoke from dirty cooking fuels results in 3.8 million deaths annually (WHO, 2018b), due to its association with illnesses such as cardiovascular disease, stroke, respiratory and lung cancer (WHO, 2018c). Regarding the environmental impacts of polluting cooking fuel, biomass consumption can lead to deforestation which can adversely affect climate change.

In Ghana, there are wide varieties of staple foods consumed by households with certain groups sharing some similarities whereas other foods are peculiar to some groups. Different cooking fuels and cooking methods such as stove, coal pot, and Liquefied Petroleum Gas (LPG) burners are used by Ghanaian households depending on the type of staple food, household size, fuel affordability and availability (Bawakyillenuo et al., 2021). Data shows that the main sources of cooking fuels in Ghana include firewood, charcoal and LPG (Ghana Statistical Service, 2014, 2019). Fuel stacking is a common practice in Ghana, particularly in the northern regions, and some of the reasons that account for fuel stacking in Ghana include the cooking method, food quantity, taste and type of cooking (Bawakyillenuo et al., 2021).

The trend in the consumption of household cooking fuel is displayed in Figs. 1 and 2. The charts show that the consumption of firewood has dropped from 41.3 percent to 33.3 percent within the 2012/2013–2016/2017 period while charcoal consumption has increased by 2.6 percentage points to 34.1 for the same period. Thus, households' use of biomass (i.e. wood and charcoal) for cooking declined from 72.8 percent to 67.4 percent for the 2012/2013–2016/2017 period. Though

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List of abbreviations

SDGs	Sustainable Development Goals
GLSS	Ghana Living Standard Survey
WHO	World Health Organization
LPG	Liquefied Petroleum Gas
UNSGSA	United Nations Secretary-General's Special Advocate for Inclusive Finance for Development
GSS	Ghana Statistical Service
OLS	Ordinary Least Squares
ATE	Average Treatment Effect
ATET	Average Treatment Effect on the treated
ATENT	Average Treatment Effect on the Untreated

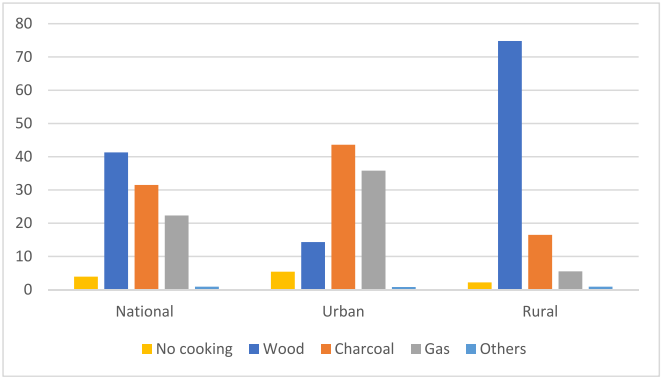

Fig. 1. Sources of cooking fuel for 2012\2013 (GLSS 6).
Data source: Ghana Statistical Service (2014)

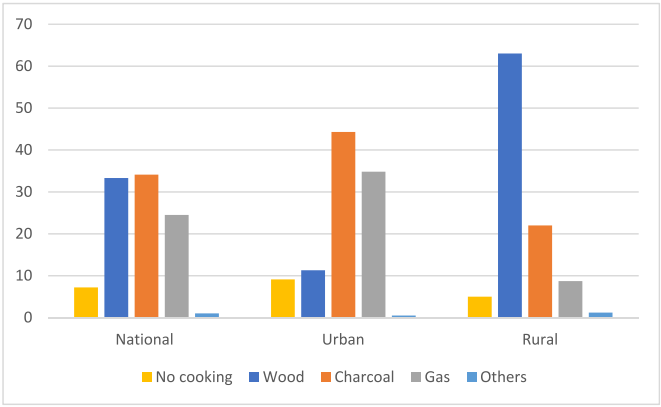

Fig. 2. Sources of cooking fuel for 2016\2017 (GLSS 7).
Data source: Ghana Statistical Service (2019)

the decline in biomass consumption is good as it reduces the depletion of the forest cover, the 67.4 percent biomass consumption is still significantly high, more so for the rural areas which is estimated at 85 percent. The high biomass consumption in the rural areas of Ghana is one of the highest in Sub-Saharan Africa (Ghana Statistical Service, 2019). Meanwhile, there has been just a slight increase in LPG consumption (i.e. 2.2 percentage points increase) from 22.3 percent in 2012/2013 to 24.5 percent in 2016/2017. It is obvious from the charts that firewood is the predominant cooking fuel in the rural areas whereas charcoal and LPG are the predominant sources of cooking fuels in the urban areas. Nevertheless, many households in Ghana use a mix of cooking fuels (i.e. "fuel stacking") as mentioned earlier and their choices depend on their resources and geographical location (Bawakyillenuo et al., 2021).

The energy ladder model explains the process through which households transition from traditional fuels (e.g., firewood), to intermediate fuels (kerosene, coal), before moving on to finally adopt clean fuels such as LPG as the economic situation of households improve (Lay et al., 2013). Households that use biomass and other traditional energy sources find themselves at the bottom end of the energy ladder. Households that adopt cleaner and modern energy options begin to climb up the energy ladder. At the highest point of the ladder are households that have fully adopted cleaner energy choices such as LPG. The underlying reasoning of the energy ladder model is that improvement in economic development indicators propel households to move up on the energy ladder (Lay et al., 2013; Modi et al., 2006).

Meanwhile, financial inclusion is considered a key enabler to the achievement of most of the SDGs of the United Nations (UNSGSA, 2018; Klapper et al., 2016) and enables the transition of households from the bottom to the top of the energy ladder (see Hsu et al., 2021 du Monde, 2017; Muller and Yan, 2018; du Monde, 2015). Evidence abounds in literature about the welfare improvement effects of financial inclusion (Caskey et al., 2006; Danquah et al., 2017; Levine, 2008; Khandker and Samad, 2014; Khandker and Samad, 2014; Luan et al., 2016). Hsu et al. (2021) in a study to evaluate a pilot microfinance intervention in Kenya to support low-income rural households to access LPG for cooking, reported that promoting LPG use as the primary household cooking fuel through microloans for portable gas stoves and LPG cylinders lead to increased adoption of LPG in beneficiary households relative to the control group. Financial inclusion, by enhancing access to financial credit and related financial services, enables low-income households to access small gas cooking stoves through a hire purchase agreement and repay in monthly instalments; and hence climb up on the energy ladder (du Monde, 2017). In effect, the capacity of households to adopt LPG as the primary source of cooking fuel and to own other modern household appliances could have a strong correlation with being financially included (Arowosoge and Faleyimu, 2011). But the question is "does financial inclusion influence households' choice of cooking fuel?".

Studies investigating the nexus between financial inclusion and cooking fuels for developing countries are scarce. The few contributors to this strand of literature include Hsu et al. (2021) and Twumasi et al. (2020). Based on a pilot microfinance initiative, Hsu et al. (2021) examined the impact of microloans on clean cooking fuel of households in Kenya and found microcredit to promote the consumption of LPG. One limitation of the study is that it focused on low-income rural households and therefore the findings cannot be generalized for other groups in Kenya. In the context of Ghana, Twumasi et al. (2020) also found credit to be positively associated with LPG consumption, but the analysis was based on rural households' dataset from four regions of Ghana. Like Hsu et al. (2021), generalization of findings for other groups is difficult in this case. In contrast, the proposed study relies on a nationally representative secondary dataset provided by the Ghana Statistical Service (GSS) for the analysis. Moreover, the two studies focused on credit access which is narrower compared to the broader definition of financial inclusion used in this study. Our outcome variables also differ in their measurement as we employ budget shares which is generally more exogenous to instrumental variables compared to dollar amounts (or any other currency values). Twumasi et al. (2020) also considered kerosene as a clean cooking fuel contrary to WHO (2021b, 2016) which list kerosene among the harmful cooking fuels. Accordingly, the present study adds kerosene to the dirty cooking fuel category. We present more robust findings as three datasets (i.e., GLSS6, GLSS 7, and the pooled form) and three different measurements of our variable of interest (i.e. financial inclusion) are employed in the analysis. We also employ different estimation technique which considers the binary nature of the endogenous variable unlike Twumasi et al. (2020). The probit two stage least square applied in this study also considers the heterogenous impact of treatment (i.e. financial inclusion) since the effect may differ for the

treated (i.e. financially included group) and the untreated (i.e. financially excluded group). Furthermore, the present study investigates the relationship at the national level and proceeds to examine the sources of heterogeneity based on gender of household head and location of households contrary to Twumasi et al. (2020). The heterogenous analysis is important for policy purposes as it informs policy makers about the relevance of financial inclusion in promoting the adoption of clean cooking technologies among vulnerable groups such as rural households (compared to their urban counterparts) and female-headed households (compared to their male counterparts) who are more exposed to the harmful consequences of dirty cooking fuels.

Thus, the study seeks to contribute to literature by making the following contributions: firstly, it uses a nationally representative dataset, which allows for a more holistic analysis compared to previous studies that only focused on four regions of the country (see Twumasi et al., 2020). Secondly, it employs a broader definition of financial inclusion, which includes savings, credit, and insurance. Previous studies for Ghana only focused on credit access. Thirdly, the study uses a more efficient estimation technique, by employing probit two-stage least squares procedure, to examine the impact of financial inclusion on the consumption of clean and dirty cooking fuels among Ghanaian households. This technique is known to produce more efficient results compared to the direct two-stage least squares method used in previous studies. It also allows for heterogeneous impact evaluation, as the effects of financial inclusion may differ between the financially included (i.e. treated) and excluded (i.e. untreated) groups. Lastly, the study performs subsample analyses by comparing the impact of financial inclusion on female-headed households to their male-headed counterparts, as well as rural households to their urban counterparts.

In the rest of the paper, details of the empirical model and the estimation technique are described in section 2 followed with the reporting of the results and discussion of findings in section 3. In section 4, the conclusion and policy implications of the study are presented.

2. Data and method of analysis

2.1. Data

The present study employs dataset from the rounds six and seven of the Ghana Living Standard Surveys (i.e., GLSS 6 and GLSS 7) carried out using two-stage stratified sampling technique in 2012/2013 and 2016/2017, respectively. These two rounds are the only GLSS dataset that contain the variables of interest (i.e., the indicators of financial inclusion and cooking fuels). Ghana Living Standard Survey is a nationally representative survey designed by the World Bank and implemented by the Ghana Statistical Services to collect information on various indicators of welfare for Ghanaian households. The indicators include information on savings, loans, income, food, health, education, housing etc. The GLSS 6 and GLSS 7 surveys selected 18,000 and 15,000 households, respectively. 16,772 households responded in the GLSS 6 (i.e., 93.2 percent response rate) while 14,009 households responded in the GLSS 7 (i.e., 93.3 percent response rate). However, due to the presence of missing data for some of the observations, the study sample reduced to 16,531 households for GLSS 6 and 13,623 households for GLSS 7. The study also pooled the two datasets to form a cross sectional panel for further analysis.

2.2. Indicators of financial inclusion

Financial inclusion is considered an important tool for the achievement of the SDGs of the United Nations (Klapper et al., 2016). The study employed multidimensional measure of financial inclusion in the analysis. Various dimensions of financial inclusion, including savings (or account holding), credit, and insurance were considered in constructing the financial inclusion indices based on recent literature (Churchill et al., 2020; Mialou et al., 2017; Park and Mercado, 2015). In order to derive the financial inclusion index, equation (1) was estimated consistent with Churchill et al. (2020) and Zhang and Posso (2019).

$$Depr_i = \frac{1}{3}F_1 + \frac{1}{3}F_2 + \frac{1}{3}F_3 \quad (1)$$

Where $Depr_i$ is the financial inclusion deprivation score, F_i is a dummy variable equal to 1 if a household does not have access to indicator i and 0 otherwise. Each of the three indicators were assigned equal weights (i.e., 1/3) such that their sum adds up to one as done in some recent financial inclusion literature (Koomson and Danquah, 2021; Churchill et al., 2020; Zhang and Posso, 2019). Following literature (Koomson and Danquah, 2021; Churchill et al., 2020; Zhang and Posso, 2019), the study sets a threshold of 0.5, where households whose deprivation scores were less than the cut-off point (i.e., 0.5) were considered financially included (treated) whereas those with higher scores above the threshold were financially excluded (untreated). Accordingly, a dummy variable equal to 1 for deprivation scores less than 0.5 was constructed to measure financial inclusion.

To ensure that results are robust, the study developed other two measures of financial inclusion indices by giving more weights to the indicators which are more important in influencing households' consumption of LPG. Out of the three indicators of financial inclusion (i.e. savings, credit and insurance), savings and credit may be more important than insurance since they can directly affect the LPG consumption of households, hence higher weights were assigned to them. First, the study assigned a weight of 0.51 to savings to make it the most important indicator while 0.245 was assigned to credit and insurance. Second, the study assigned equal weight of 0.4 to both savings and credit (while 0.2 was assigned to insurance) and at the same time the cut-off point was raised to 0.7 to make savings and credit the most important indicators. These checks are important as it helps to discover whether our estimated models are sensitive to alternative weights and cut-offs as performed in Koomson and Danquah (2021).

2.3. Empirical model

The theoretical background of our empirical model is the Working-Leser model, where budget share is specified as a linear function of the log of total expenditure. Empirical studies on budget shares which are also based on the Working-Leser model include Randazzo and Piracha (2019), Adams and Cuecuecha (2013) and Adams and Cuecuecha (2010). We specify our empirical model as:

$$H_{ij} = \gamma + \omega F_i + \varnothing \log INC_i + X_i^{'}\beta + \varepsilon_{ij} \quad (2)$$

Where H_{ij} is household i share of good j in the total housing expenditure. Where j is made up of housing expenditures categorized into three groups: LPG consumption, dirty cooking fuel consumption and other housing expenditures (Table 1). The study focuses on the first two to achieve its objectives. This suggests that H represents the annual housing budget of the two categories of housing expenditures: clean cooking fuel (proxied by LPG) and dirty cooking fuel (proxied by kerosene,

Table 1
Description of housing expenditure categories.

Housing expenditure category	Description
LPG	Expenditure on cooking gas
Dirty cooking fuels	Expenditure on kerosene, firewood charcoal and other fuels
Other housing expenditures	Expenditure on rent, maintenance and repair of dwelling, electricity, water supply, sewerage etc

firewood charcoal and other fuels).[1] Financial inclusion which is our variable of interest is represented by F_i, log of income (proxy for expenditure) is represented by $\log INC_i$, while $X_i^{'}$ is the other control variables (Table A1 in the **Appendix** provides details). Concerning the parameters, γ is the intercept while ω and $\varnothing$ measure the marginal effects of financial inclusion and household income respectively. On the other hand, β represents a vector of parameters for the control variables.

2.4. Estimation technique

Estimating equation (2) by simple Ordinary Least Squares (OLS) may give rise to endogeneity because of the issues of reverse causality and omitted variable bias. In the case of reverse causality, having access to financial services such as savings and credit may indeed influence households on their choice of cooking fuel. However, the type of cooking fuel (clean or dirty) used by households may also indicate their ability to access financial services. The issue of omitted variable bias may also arise from the exclusion of some unobservable variables that have a direct correlation with financial inclusion. Therefore, the study applied instrumental variable (IV) technique[2] to address the endogeneity issue. An IV approach requires that the instrument must satisfy two conditions: (1) must be strongly correlated with the endogenous variable (i.e. financial inclusion in this case), (2) must be exogenous – i.e. uncorrelated with the dependent variable (in this case the budget shares). Finding appropriate instrument which satisfies these two conditions is crucial for addressing the endogeneity problem. The present study uses distance to nearest financial institution as instrument following recent studies such as Koomson et al. (2020), Koomson and Danquah (2021), and Ibrahim and Aliero (2020). There is sufficient evidence in literature that distance to nearest financial institution is strongly correlated with financial inclusion (Koomson and Danquah, 2021; Ibrahim and Aliero, 2020; Koomson et al., 2020; Demirgüç-Kunt and Klapper, 2013). In practice, it is also common to find people living close to financial institutions to have access to financial services than those staying farther away. On the issue of the exogeneity of the instrument, one key factor that can influence distance is income level (Bair and Tritah, 2019). People would usually want to settle in areas where they can easily access essential services, and therefore income level is usually the determinant of who gets to stay in those places. In addition, providers of financial services will also want to extend their branches to areas dominated by the rich. Thus, the role income plays in influencing distance to financial institution cannot be overlooked, hence the study controlled for income level of households to ensure the exogeneity of the instrumental variable. Since there is only one instrument for financial inclusion the model is exactly identified.

The estimation technique applied to address the issue of endogeneity is the Probit two-stage least square with heterogenous response to treatment. Unlike the direct two stage least square, the Probit two-stage least square considers the binary nature of the endogenous variable (Cerulli, 2014), and it involves the following steps: first, the study runs probit regression (with financial inclusion) as the dependent variable on the instrument to obtain the predicted probability of treatment (i.e., probability of financial inclusion) as shown in (3).

$$Pr(Y = F_i|X_i, Z_i) = c + \varnothing\, Distance_i + \gamma \log INC_i + X_i^{'}\beta + u_i \tag{3}$$

Where *Distance* (or Z_i) is the instrument measuring distance to the nearest financial institution, while $X_i^{'}$ is a vector of control variables defined in Table A1 (in the **Appendix**). From (1), we obtain the predicted probability of being financially included (represented by P_F). Next, the study performs two stage least square by running F_i on P_F at the first stage to obtain the fitted values of F_i as shown in (4).

$$F_i = \partial + \varnothing P_F + \vartheta \log INC_i + X_i^{'}\beta + v_{ij} \tag{4}$$

The fitted values of financial inclusion (i.e., $\widehat{F_i}$) is obtained from (4) to perform the second stage which involves regressing H_{ij} on $\widehat{F_i}$ as expressed in (5).

$$H_{ij} = \sigma + \varphi \widehat{F_i} + \vartheta \log INC_i + X_i^{'}\beta + \varepsilon_{ij} \tag{5}$$

The parameter φ in (5) is the Average Treatment Effect (ATE) and it is considered more efficient than a direct two stage least squares regression (Cerulli, 2014). But in practice, the effect of financial inclusion may be heterogenous, therefore the study includes additional regressors of the form $(X_i - \mu_X)\widehat{FI_i}$ following Cerulli (2014) to estimate the Average Treatment Effect on the treated (ATET) and the Average Treatment Effect on the Untreated (ATENT). The study applied bootstrapping to obtain standard errors for testing the statistical significance of the ATET and the ATENT parameters.

3. Results and discussion

3.1. Descriptive statistics

The present study investigates the impact of financial inclusion on clean cooking fuel (i.e., LPG) in Ghana. The study compares the treatment effect of financial inclusion on LPG versus other dirty cooking fuels. The outcome variables are therefore categorized into two, namely clean cooking fuel (proxied by LPG) and dirty cooking fuel (proxied by kerosene, firewood charcoal and other fuels). Table 2 presents the descriptive statistics of these variables used in the study.

Table 2 shows that the share of household housing expenditure spent on clean cooking fuel is much smaller relative to the amount spent on dirty cooking fuels according from the GLSS 6 and GLSS7 datasets. On average, Ghanaian households spend nearly 10 percent of their household budget on dirty cooking fuels and allocate about 1 percent of the budget to LPG consumption. In the case of the treated households, members spend 2 percent (GLSS 7) or 3 percent (GLSS 6) on LPG consumption. The t-statistics also show that the LPG consumption gap between the treated and the untreated households is statistically significant.

Table A2 (in the **Appendix**) presents descriptive statistics on the subsamples. Female-headed households appear to spend more on cooking fuel than their male counterparts as they dominate in expenditure in both clean and dirty cooking fuels. Urban households dominate their rural counterparts on the use of clean cooking fuel while rural households spend more on dirty cooking fuels. The relative scarcity of LPG and the easy and cheaper access to the dirty cooking fuels in the rural areas may account for this phenomenon. Table A2 (in the **Appendix**) also shows that female-headed households lag their male counterparts on financial inclusion. As expected, rural households also lag urban households on financial inclusion.

The Probit regression results are reported in Table 3 (and Table A3 in the **Appendix** for robustness checks) for the three datasets. As expected, the instrumental variable, (i.e. distance to nearest financial institution) is inversely related to financial inclusion and highly significant. The inverse relationship suggests that households who live closer to financial institutions are more likely to be financially included than their counterparts who live farther away. The high significance level of the instrument is also an indication of a high correlation between the instrument and the endogenous variable (i.e., financial inclusion). The robustness check results displayed in Table A3 (in the **Appendix**) also provide evidence of strong inverse relationship between the instrument and the endogenous variable. The strong correlation between the

[1] 90 percent of wood produced in the Sub-Saharan Africa is used as fuel (Food and Agriculture Organization, 2021). The most utilized sources of cooking fuels in Ghana are firewood and charcoal (Energy Commission, 2019).

[2] Studies on budget shares which applied instrumental variable technique to solve the endogeneity issues include Adams and Cuecuecha (2010) and Adams and Cuecuecha (2013).

Table 2
Summary statistics (mean values) of the share of household housing expenditure - full samples.

	GLSS 7				GLSS 6				POOLED			
	Full	Treated	Untreat	*t*-test	Full	Treated	Untreat	*t*-test	Full	Treated	Untreat	*t*-test
LPG	0.0140	0.0254	0.0104	−0.0150***	0.0135	0.0314	0.0080	−0.0234***	0.0137	0.0286	0.0091	−0.0196***
Dirty cooking fuel	0.0952	0.0995	0.0939	−0.0056*	0.0961	0.0929	0.0971	0.0043	0.0957	0.0959	0.0957	−0.0003
Other housing expenditures	0.8907	0.8751	0.8958	0.0206***	0.8904	0.8757	0.89485	0.0191***	0.8905	0.8755	0.8953	0.0198***
Total	**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**1.00**		**1.00**	**1.00**	**1.00**	
Observations	13,623	3310	10,313		16,531	3883	12,648		30,154	7193	22,961	

Note: ***p < 0.01, **p < 0.05, *p < 0.1. t-statistic computed with unequal variance. Treated = financially included households, Untreat = financially excluded households.

Table 3
Probit regression.

	GLSS 7	GLSS 6	Pooled
Distance to nearest financial institution (in kilometers)	−0.0200***	−0.0071***	−0.0146***
Total household income per capita (in natural log)	0.1985***	0.2331***	0.2079***
Gender (Female = 1, Male = 0)	0.0728**	0.0228	0.0459*
Household head is employed (Yes = 1, No = 0)	0.0773**	0.0130	0.0291
Size of household	0.1445***	0.1187***	0.1286***
Size of household squared	−0.0051***	−0.0046***	−0.0047***
Age of household head	0.0017	0.0027**	0.0015*
Number of male household members under 5	−0.0737***	−0.0546**	−0.0670***
Number of female household members under 5	−0.0080	−0.0838***	−0.0521***
Number of household members within 15–24 age range	−0.0133	0.0184	0.0052
Household members over 64 years	0.0216	−0.0169	0.0084
Literacy status of household head (Yes = 1, No = 0)	0.3668***	0.6085***	0.4920***
Household head's marital status (base category = married)			
Consensual union	−0.1095**	−0.1592***	−0.1469***
Separated	−0.0411	−0.3560***	−0.2012***
Divorced	−0.2285***	−0.2867***	−0.2540***
Widowed	−0.1819***	−0.1724***	−0.1719***
Never married	−0.1090**	−0.0981**	−0.1245***
Rural dummy (rural = 1, 0 otherwise)	−0.2111***	−0.5103***	−0.3622***
Nationality (Ghanaian = 1, 0 otherwise)	0.2367**	0.3330***	0.2639***
Savannah dummy (savannah = 1, 0 otherwise)	0.5002***	0.1882***	0.2851***
Forest dummy (forest =1, 0 otherwise)	0.2784***	0.1762***	0.1520***
Coastal dummy (coastal =1, 0 otherwise)	0.1143*	0.0210	−0.0152
Year	–	–	−0.0672***
Constant	−3.2703***	−3.4739***	−3.1138***
Observation	13,623	16,531	30,154

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors.

instrument and the endogenous variable is one of the requirements for a valid instrument. The second requirement which borders on the exogeneity of the instrument cannot be tested in an exact identified case like this study. Nevertheless, the strong correlation shown in Tables 5 and A1 are not sufficient to draw conclusions in the absence of an F-test for weak instrument. Accordingly, the F-tests for weak instrument have been reported in Table 5.

Concerning the key control variables, household income shows positive correlation with financial inclusion, suggesting that increase in household income increases the likelihood of patronizing financial products. The same positive relationship is found in the robustness checks (Table A3 in the **Appendix**). Household heads who are employed are also likely to be financially included (though this is only significant in GLSS 7) than their unemployed counterparts. This is expected as workers, especially those in the formal sector usually require accounts to receive payments of their wages/salaries. They are also considered credit worthy than their unemployed counterparts. However, the positive relationship is not supported in Table A3. Similarly, gender also shows positive relationship with financial inclusion in Table 3, but inverse relationship is discovered in the robustness checks (i.e., Table A3) due to differences in the measurement of the financial inclusion variables. However, literacy shows consistency in the sign and significance level across the three datasets in Table 3 and the robustness checks in Table A3. The positive relationship implies that household with literate heads are more likely to be financially included compared to their illiterate counterparts. The location variable also shows consistency like the literacy variable. The inverse relationship suggests that households in the rural areas are less likely to be financially included compared to their urban counterparts.

The analysis of the study is divided into two broad sections. The first part investigates the relationship between financial inclusion and household cooking fuels in Ghana based on the full sample datasets. In this section, the effect of financial inclusion on clean cooking fuel is compared with dirty cooking fuels. The ATE results followed by the ATET and the ATENT results, in that order, are presented and discussed (see Table 4, Table A4, and Table A5 in the **Appendix**). The second section is based on the subsample analyses, where the treatment effects of financial inclusion on clean cooking fuel is compared based on gender (i.e., male-headed households versus female-headed households) and location (i.e., rural households versus urban households).

The results in Table 4 shows that financial inclusion has positive relationship with clean cooking fuel (LPG) but inverse relationship with dirty cooking fuels. If all households were financially included, they would spend approximately 6 percent more on LPG, while their consumption of dirty cooking fuels declines by 55 percent according to the GLSS 7 dataset. While the consumption of LPG shows a steady increase, dirty cooking fuels show a sharp decline from 10 percent in 2012/2013 to 55 percent in 2016/2017 (though the Pooled dataset shows a decline of 36 percent) arising from financial inclusion. The robustness results reported in the **Appendix** (see Table A4 and Table A5) also give evidence of increased LPG consumption and a reduction in dirty cooking fuels, but the impact of financial inclusion is relatively smaller. This may be due to the differences in the measurement/definition of financial inclusion in the estimated models. The reduction in the consumption of polluting cooking fuels and the rise in the adoption of cleaner cooking fuel (LPG) among financially included households may suggest that financial inclusion provides a safe place for households to save in order to adopt cleaner cooking technologies. It may also mean that households are able to borrow from formal financial institutions at relatively lower interest rates (compared to borrowing from informal sources) to facilitate their switch to LPG usage. Therefore, financial inclusion may help Ghanaian households to transition from the use of polluting cooking technologies to the adoption of cleaner cooking technologies like LPG.

Since the effect of financial inclusion may be heterogenous, the study

Table 4
Effect of financial inclusion on household cooking fuels in Ghana.

	LPG cooking fuel			Kerosene, firewood charcoal and other fuel		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
Financial inclusion – FI (1)	0.0607***	0.0459***	0.0635***	−0.5476***	−0.1010*	−0.3559***
Total household income per capita (in natural log)	−0.0004	0.0001	−0.0008	0.0349***	0.0097***	0.0222***
Gender (Female = 1, Male = 0)	−0.0020	0.0023	2.38e-05	0.0925***	0.0430***	0.0630***
Household head is employed (Yes = 1, No = 0)	0.0003	−0.0034**	−0.0004	−0.0132	0.0029	−0.0196***
Size of household	−0.0007	−0.0006	−0.0012**	0.0117	0.0012	0.0071
Size of household squared	3.34e-05	0.0001**	0.0001***	0.0001	−0.0002*	−0.0002
Age of household head	0.0002**	−7.75e-06	0.0001**	−0.0006	−1.58e-05	−0.0003
Number of male household members under 5	0.0016	−0.0017**	−0.0004	−0.0041	0.0005	0.0002
Number of female household members under 5	−0.0003	−0.0005	−0.0004	0.0013	0.0089**	0.0035
Number of household members within 15–24 age range	−0.0002	−0.0001	−0.0005	0.0041	−0.0047*	−0.0013
Household members over 64 years	−0.0019	0.0001	−0.0010	−0.0036	−0.0072	−0.0069
Literacy status of household head (Yes = 1, No = 0)	−0.0005	0.0011	−0.0005	0.0509***	0.0330***	0.0503***
Household head's marital status (base category = married)						
Consensual union	−0.0004	0.0034*	0.0028	−0.0335*	0.0243**	−0.0060
Separated	0.0115**	−0.0030	0.0029	−0.0390	−0.0125	−0.0280**
Divorced	−0.0034	−0.0023	−0.0037	0.0005	−0.0120	−0.0066
Widowed	0.0006	−0.0022	−0.0010	−0.0259	0.0004	−0.0091
Never married	0.0017	0.0014	0.0019	−0.0539*	−0.0276**	−0.0371***
Rural dummy (rural = 1, 0 otherwise)	−0.0002	0.0031*	0.0014	−0.0060	−0.0585***	−0.0435***
Nationality (Ghanaian = 1, 0 otherwise)	−0.0137*	−0.0027	−0.0066**	0.0400	−0.0118	0.0078
Savannah dummy (savannah = 1, 0 otherwise)	−0.0208***	−0.0112***	−0.0141***	0.0866***	0.0323***	0.0386***
Forest dummy (forest =1, 0 otherwise)	−0.0217***	−0.0136***	−0.0152***	0.0407	0.0496***	0.0288**
Coastal dummy (coastal =1, 0 otherwise)	−0.0179**	−0.0095**	−0.0120***	0.1018***	0.1696***	0.1280***
Year	–	–	0.0008	–	–	−0.0102***
Constant	0.0292*	0.0151**	0.0220***	−0.2113**	0.0150	−0.0472
Observations	13,623	16,531	30,154	13,623	16,531	30,154

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. Additional regressors of the form $(X_i - \mu_X)\widehat{F}_i$ were included to measure heterogenous impacts of FI but not reported.

estimates both the ATET and the ATENT. The ATET examines the effect of financial inclusion on the outcome variables for the treated group (i.e. financially included households) whereas ATENT predicts the effect of financial inclusion on the untreated households (i.e. financially excluded households). Table 5 presents the results for the ATET and the ATENT groups. The baseline result is presented in panel A while panel B and C provide robustness checks based on different measurements of the financial inclusion variable. The ATET coefficient of 0.066 (or 0.055 in the case of GLSS 6) suggests that financially included households spend approximately 7 percent (or 6 percent for GLSS 6) more on LPG than what they would spend if they were not financially included. While the ATENT coefficient of 0.059 predicts that financially excluded households would spend approximately 6 percent more on LPG if they were financially included. In the case of the dirty cooking fuels, all the three datasets show inverse relationship for the ATET (though GLSS 7 is not significant) and ATENT (both GLSS 7 and GLSS 6 are not significant). These results suggest that financial inclusion is associated with increased consumption of LPG and reduction in dirty cooking fuels which is consistent with the ATE results discussed earlier. The robustness checks in panel B and C also confirm the positive association of financial inclusion with LPG consumption and the inverse relationship between financial inclusion and dirty cooking fuels.

The significant reduction in the consumption of polluting cooking fuels among financially included households is good for Ghana because of the high air pollution emitted from households. According to WHO (2021a), air pollution from households during non-Harmattan periods (when there is less desert dust) accounts for 45 percent of outdoor air pollution in Accra. WHO (2021a) estimated that 20,988 premature deaths in Ghana in 2016 was associated with air pollution mainly caused by polluting cooking technologies such as mixing polluting stoves with firewood or charcoal to cook (WHO, 2018b). This shows the extent of the adverse impacts polluting cooking fuels have on the health of Ghanaian households, and financial inclusion is a key facilitator in the transition to cleaner energy technologies like the adoption of LPG to cook. Thus, financial inclusion can be a tool to achieving the United Nations' SDG goal 7 of affordable and clean energy use (SDG 7), which may in turn be the gateway to achieving many of the other SDGs such as promotion of good health and well-being (SDG 3), since many illnesses including cardiovascular diseases, acute lower respiratory infections and chronic obstructive pulmonary disease are linked to air pollution (WHO, 2018c); SDG 5 of gender equality because women and children are disproportionately exposed to the health hazards of using polluting cooking fuels since they are responsible for collecting firewood and spending more time in the kitchen and thus could benefit substantially from the use of clean cooking fuel like LPG; SDG 11 of promoting sustainable cities and communities which could come about from reduced air pollution in the communities and cities; and lastly, SDG 13 which borders on climate action since LPG cooking fuel can contribute to a low carbon future.

In Ghana, efforts have been made by governments to promote LPG adoption as a substitution for polluting technologies such as firewood or charcoal. National LPG programme was introduced in Ghana in 1990 to distribute free LPG cylinders as a way of promoting the transition from wood fuels to LPG adoption (WHO, 2021a). In 2018, energy policy which aimed at increasing LPG usage to 50 percent by the year 2020 was set in motion. Despite government efforts, these policies have achieved little due to some challenges in the LPG industry. These include high cost of refilling LPG cylinders, lack of reliable supply chain for LPG, lack of regulatory environment and poor sensitization about the health and environmental benefits of LPG usage (Edjekumhene et al., 2007). Financial inclusion may be an important tool required to facilitate the switch to clean cooking fuel in Ghana as results in the study show that financially included households significantly reduce their consumption of wood fuels to consume LPG. This may imply that the availability of credit facilities or a safe place to save can play a significant role in the switch.

The distribution for ATE, ATET and ATENT for the LPG models and the dirty cooking fuel models have been provided in Figs. 3–8. The graphs show that ATET has the highest modal values for each of the graphs. The distribution of the LPG models (as provided by the ATE,

Table 5
Heterogenous effects of financial inclusion on household cooking fuels in Ghana.

Panel A	Baseline model: FI (1)					
	LPG cooking fuel			Kerosene, firewood charcoal and other fuels		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
ATET	0.066***	0.055***	0.069***	−0.526	−0.1385 **	−0.352***
ATENT	0.059***	0.043***	0.062***	−0.554	−0.0895	−0.357***
Observations	13,623	16,531	30,154	13,623	16,531	30,154
Weak IV test						
Kleibergen-Paap rk Wald F statistic				89.338	252.514	277.179
Panel B	FI (2) - Robustness check					
	LPG cooking fuel			Kerosene, firewood charcoal and other fuels		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
ATET	0.032***	0.030**	0.033***	−0.260***	−0.134***	−0.195***
ATENT	0.018***	0.017*	0.021***	−0.232***	−0.095**	−0.155***
Observations	13,623	16,531	30,154	13,623	16,531	30,154
Weak IV test						
Kleibergen-Paap rk Wald F statistic				252.050	226.565	476.643
Panel C	FI (3) - Robustness check					
	LPG cooking fuel			Kerosene, firewood charcoal and other fuels		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
ATET	0.032***	0.029***	0.033***	−0.259***	−0.125***	−0.190***
ATENT	0.017***	0.015*	0.020***	−0.229***	−0.084**	−0.150***
Observations	13,623	16,531	30,154	13,623	16,531	30,154
Weak IV test						
Kleibergen-Paap rk Wald F statistic				254.784	231.654	481.964

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. Bootstrap replications specified was 1000. FI(1) - FI(3) are the three measures of financial inclusion.

ATET and ATENT graphs) is concentrated on the positive values whereas in the case of the dirty cooking fuels, the distribution of the models is concentrated on the negative. This is consistent with the results reported in the tables suggesting that financial inclusion increases the use of LPG but reduces the consumption of dirty cooking fuels (see Fig. 4) (see Fig. 5) (see Fig. 6) (see Fig. 7) (see Fig. 8).

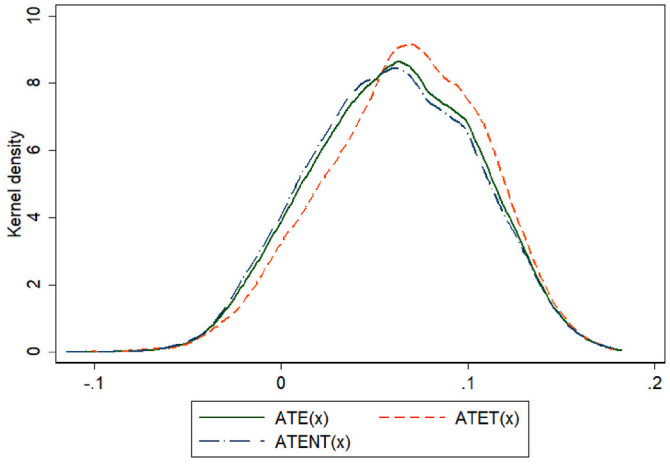

Fig. 3. LPG-comparison of ATE(x), ATET(x), ATENT(x) (GLSS 7).

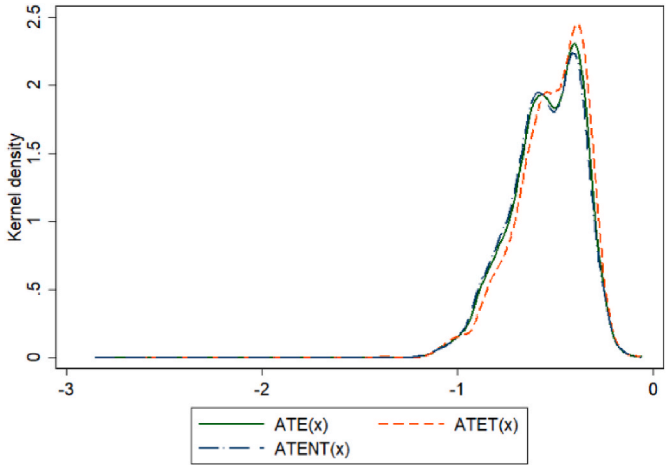

Fig. 4. Dirty fuel-comparison of ATE(x), ATET(x), ATENT(x) (GLSS 7).

3.2. Effect of financial inclusion on consumption of cooking fuels: female- versus male-headed households

The ATET and ATENT of male-headed households and female headed households are reported in Table 6. Generally, the baseline financial inclusion variable turned out to be insignificant in most cases while the other two measures of financial inclusion were relatively more

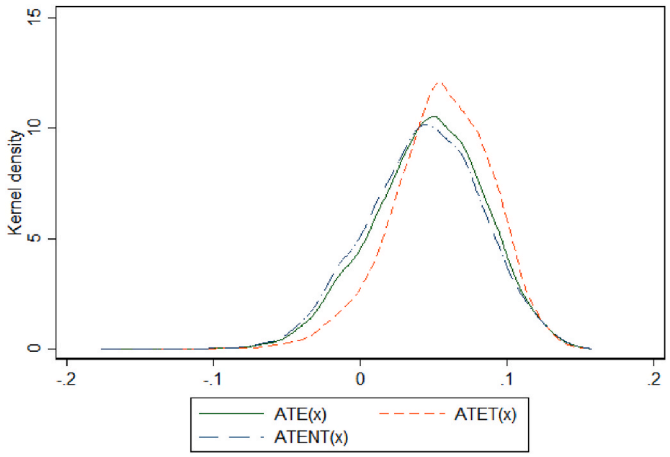

Fig. 5. LPG-comparison of ATE(x), ATET(x), ATENT(x) (GLSS 6).

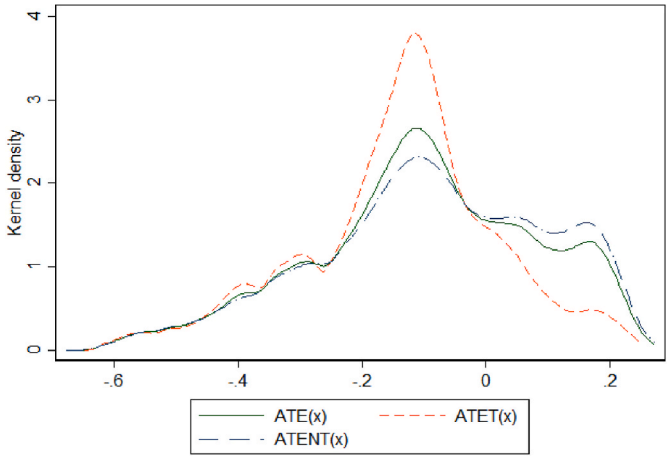

Fig. 6. Dirty fuel-comparison of ATE(x), ATET(x), ATENT(x) (GLSS 6).

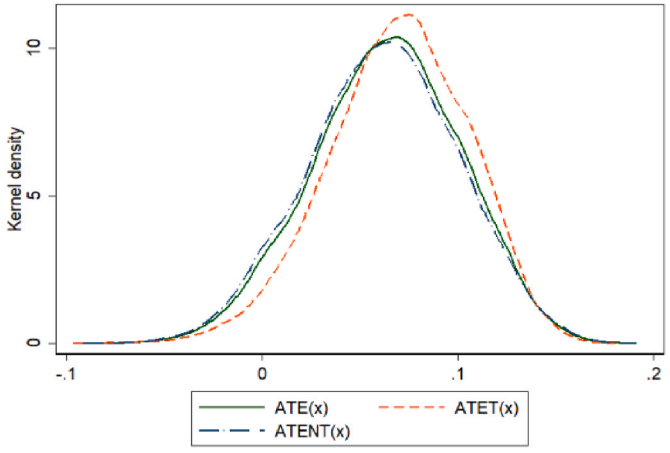

Fig. 7. LPG-comparison of ATE(x), ATET(x), ATENT(x) (pooled).

significant in the LPG models. According to the GLSS 6 results, the effect of financial inclusion on LPG consumption turned out to be insignificant for female-headed households and with smaller coefficients compared to their male counterparts whose ATET values were statistically significant for all the three measures of financial inclusion. However, for the GLSS 7 dataset, the ATET of female-headed households show significant impact of financial inclusion on LPG consumption in two cases, just like their

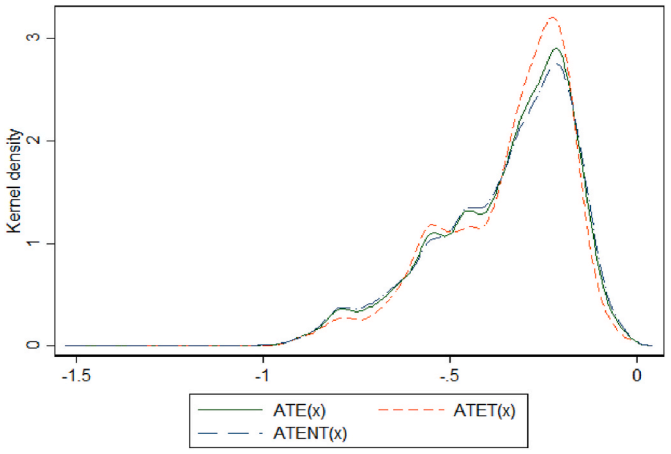

Fig. 8. Dirty fuel-comparison of ATE(x), ATET(x), ATENT(x) (Pooled).

male counterparts. Albeit the coefficients of the female-headed households are larger than their male counterparts. Thus, the results of the two datasets provide evidence that over time, financially included female-headed households spend more of their housing budget on LPG than male-headed households. As for the dirty cooking fuels, the two datasets consistently show that financially included female-headed households reduce their consumption of polluting cooking fuels by a larger share than male-headed households. This finding suggests that financial inclusion can improve the health and economic well-being of women since they spend more time in the kitchen than men. Women and children are usually responsible for the collection of firewood (WHO, 2021a), therefore the reduction in the consumption of the polluting fuels means freeing up some time from the collection of firewood for other economic use or personal development. Thus, women can spend more time on education or other income generating activities which can improve their economic well-being and hence reduce the existing gender gap, which is one of the SDG goals (SDG 5). Less exposure to polluting fuels can also improve the health status of women and increase their life expectancy.

3.3. Effect of financial inclusion on consumption of cooking fuels: rural versus urban households

Table 7 reports the results of the impact of financial inclusion on the consumption of cooking fuels in rural and urban households. The ATET and the ATENT show that financial inclusion has positive relationship with LPG consumption in both rural and urban areas. However, with the polluting fuel models, the results show inverse relationship with financial inclusion for the two household types. This shows that financial inclusion increases the consumption of LPG but reduces polluting cooking fuel consumption in both rural and urban households. In the case of the LPG models, both the ATET and the ATENT coefficients for urban households appear to be generally larger than the rural households in GLSS 7 and GLSS 6, implying that financial inclusion results in larger increase in the consumption of LPG in urban areas than rural areas. Awareness campaign about the health and environmental benefits of LPG consumption may not be widespread in the rural areas (compared to the urban) and therefore financially included rural households may continue to use firewood as cooking fuel since it is freely available for gathering in some cases in the rural areas. The lack/limited availability of LPG in rural areas may also limit the impact of financial inclusion on the consumption of LPG. A study by Asante et al. (2018) found that distance to LPG filling stations was cited as one of the major causes of low consumption of LPG in the rural areas of Ghana. The results on dirty cooking fuel show that financial inclusion results in the reduction of polluting cooking fuel consumption in both urban and rural areas. The GLSS 6 dataset shows a larger reduction for urban households whereas the GLSS 7 dataset reports larger coefficients for rural households. Like

Table 6
Effect of financial inclusion on cooking fuels: female-headed versus male-headed households.

Panel A: Female-headed households												
	Clean cooking fuel (LPG)						Dirty cooking fuels (Kerosene, firewood charcoal and other fuels)					
	GLSS 7			GLSS 6			GLSS 7			GLSS 6		
	FI (1)	FI (2)	FI (3)	FI (1)	FI (2)	FI (3)	FI (1)	FI (2)	FI (3)	FI (1)	FI (2)	FI (3)
ATET	0.087	0.036***	0.034***	0.049	0.025	0.024	−0.8017	−0.4470***	−0.4254***	−0.0933	−0.1641*	−0.1503*
ATENT	0.077	0.022*	0.020	0.034	0.015	0.013	−0.7906	−0.3954***	−0.3733***	−0.0289	−0.1297	−0.1130
Obs	4236	4236	4236	4661	4661	4661	4236	4236	4236	4661	4661	4661
Weak IV test												
Kleibergen-Paap rk Wald F statistic							10.071	51.582	53.642	62.982	82.205	85.756
Panel B: Male-headed households												
ATET	0.055	0.024**	0.024**	0.064**	0.033**	0.032**	−0.428	−0.2347*	−0.2342***	−0.1312	−0.1022*	−0.0926*
ATENT	0.046	0.011	0.010	0.052	0.016	0.015	−0.449	−0.1856	−0.1857***	−0.0774	−0.0483	−0.0385
Obs	9387	9387	9387	11,870	11,870	11,870	9387	9387	9387	11,870	11,870	11,870
Weak IV test												
Kleibergen-Paap rk Wald F statistic							83.591	182.388	184.034	179.488	126.999	131.372

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. Bootstrap replications specified was 1000. FI(1) - FI(3) are the three measures of financial inclusion.

Table 7
Effect of financial inclusion on cooking fuels: rural versus urban households.

Panel A: Rural households												
	Clean cooking fuel (LPG)						Dirty cooking fuels (Kerosene, firewood charcoal and other fuels)					
	GLSS 7			GLSS 6			GLSS 7			GLSS 6		
	FI (1)	FI (2)	FI (3)	FI (1)	FI (2)	FI (3)	FI (1)	FI (2)	FI (3)	FI (1)	FI (2)	FI (3)
ATET	0.037	0.019***	0.017***	0.065	0.033*	0.033	−0.7091	−0.318***	−0.310***	−0.139	−0.116*	−0.114
ATENT	0.030	0.009	0.008	0.070	0.031*	0.030	−0.7654	−0.335***	−0.325***	−0.159	−0.122**	−0.120
Obs	7865	7865	7865	9271	9271	9271	7865	7865	7865	9271	9271	9271
Weak IV test												
Kleibergen-Paap rk Wald F statistic							59.672	134.718	139.054	105.949	152.359	155.146
Panel B: Urban households												
ATET	0.091	0.059**	0.062*	0.063***	0.043***	0.043***	−0.2266	−0.126*	−0.129*	−0.289	−0.297***	−0.282***
ATENT	0.092	0.049**	0.051*	0.065***	0.036***	0.036***	−0.231	−0.105	−0.106	−0.295	−0.284***	−0.264***
Obs	5758	5758	5758	7260	7260	7260	5758	5758	5758	7260	7260	7260
Weak IV test												
Kleibergen-Paap rk Wald F statistic							28.260	99.718	97.629	43.012	47.470	53.235

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. Bootstrap replications specified was 1000. FI(1) - FI(3) are the three measures of financial inclusion.

the gender analysis in the previous section, the results means that over time, financial inclusion appears to have larger pollution reduction effect (i.e., pollution from household cooking fuel) in rural areas than urban areas.

4. Conclusion and policy implications

Financial inclusion plays a key role in achieving most of the SDGs of the United Nations. On the issues of climate change, financial inclusion is one of the tools needed to empower Ghanaian households to assist them transition from dirty cooking fuels to clean cooking fuels. The current study examines the impact of financial inclusion on clean cooking fuel versus dirty cooking fuel consumption in Ghana.

To ensure our results are robust, we employed three datasets (GLSS 6, GLSS7, and the pooled datasets) and three different measures of financial inclusion variables computed by varying the weights of the indicators of financial inclusion (i.e. account/savings, credit and insurance) and cut offs. The Probit two-stage least square estimation technique was applied in the study with distance to nearest financial institution as instrument. The ATE, ATET and ATENT were estimated, and the results show that financial inclusion leads to a reduction in dirty cooking fuels consumption and an increase in clean cooking fuel (LPG) consumption in Ghana, respectively. In Ghana, LPG as a form of clean cooking fuel is relatively cheaper than other clean alternatives like electricity. This implies that financial inclusion could result in the achievement of the SDG 7 (affordable and clean energy) in Ghana and fast-track the achievement of other SDGs such as SDG 3, SDG 5, SDG 11 and SDG 13.

The subsample results on gender show that over time, the effect of financial inclusion on consumption of clean cooking fuel is relatively

more significant in female-headed households compared to their male counterparts. The findings of the study indicate that financially included female-headed households seem to increase their consumption of LPG and at the same time reduce their consumption of polluting cooking fuels than their male counterparts. The study therefore advocates for increased promotion of financial inclusion of women to facilitate the transition to clean cooking technologies in Ghana. According to the World Bank Global Findex (2017) dataset, greater proportion of Ghanaian women than their male counterparts are unbanked. Hence, increasing the financial inclusion of women may significantly improve access to finance for adopting clean cooking fuel technologies and serve as an enabler to the achievement of the SDG7 (affordable and clean energy consumption) as well as SDG 5 (gender equality).

Concerning rural versus urban households, the results of the study show that financially included rural households reduce their consumption of dirty cooking fuels more than their urban counterparts. According to the Ghana Statistical Service (2019), rural households dominate in the use of wood cooking fuel in Ghana, where 63 percent use wood for cooking. Therefore, continuous provision of access to finance to both rural and urban financially excluded households will significantly speed up the transition to clean cooking fuels and reduction of household air pollution from dirty cooking fuels.

The results further show that financially included rural households lag their urban counterparts in LPG consumption. But this phenomenon may be due to the poor awareness campaign about the health and environmental benefits of LPG as well as the limited availability of LPG filling stations and the high price of LPG. The latter may be overcome if financial inclusion improves the standard of living of rural households. This suggests that designing financial services which meet the needs of rural households while at the same time structuring awareness campaign programmes to educate rural households about the benefits of switching to LPG may help in the transition of rural households.

CRediT authorship contribution statement

Eric Abokyi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Paul Appiah-Konadu:** Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Eric Fosu Oteng-Abayie:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Kwabena Fio Tangato:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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

Data availability

Data will be made available on request.

Appendix

Table A1
Definition of variables

Variable	Variable type	Definition
Instrumental variable:		
Distance to nearest financial institution	Continuous	Regional average distance (in kilometers) to nearest financial institution (based on 10 regions)
Household characteristics:		
Financial inclusion – FI (1)	Dummy	If household is financially included (Yes = 1, No = 0) – equal assigned weights.
Financial inclusion – FI (2)	Dummy	If household is financially included (Yes = 1, No = 0) – higher weight assigned to account
Financial inclusion – FI (3)	Dummy	If household is financially included (Yes = 1, No = 0) – higher weight assigned to account and credit with higher cut-off
Total household income per capita (in natural log)	Continuous	Annual total gross income per capita of households
Gender of household head	Dummy	Female = 1, Male = 0
Household head is employed (Yes = 1, No = 0)	Dummy	If household head is employed. Yes = 1, No = 0
Size of household	Discrete random	Number of people in a household
Size of household squared	Discrete random	
Age of household head	Continuous	Age in years
Number of male household members under 5	Discrete random	Number of male children within the age bracket 0–4years
Number of female household members under 5	Discrete random	Number of female children within the age bracket 0–4years
Number of household members within 15–24 age range	Discrete random	Number of members within the age bracket 15–24years
Household members over 64 years	Discrete random	Number of members over 64 years
Literacy status of household head (Yes = 1, No = 0)	Dummy	Household head has attended school. Yes = 1, No = 0
Nationality (Ghanaian = 1, 0 otherwise)	Dummy	Household head is a Ghanaian: Yes = 1, No = 0
Household head marital status		
Married (Yes = 1, 0 otherwise)	Dummy	Household head is married. Yes = 1, No = 0
Consensual union (Yes = 1, 0 otherwise)	Dummy	Household head in consensual union. Yes = 1, No = 0
Separated (Yes = 1, 0 otherwise)	Dummy	Household head is separated. Yes = 1, No = 0
Divorced (Yes = 1, 0 otherwise)	Dummy	Household head is divorced. Yes = 1, No = 0
Widowed (Yes = 1, 0 otherwise)	Dummy	Household head is widowed. Yes = 1, No = 0

(*continued on next page*)

Table A1 (*continued*)

Variable	Variable type	Definition
Never married (Yes = 1, 0 otherwise)	Dummy	Household head is never married. Yes = 1, No = 0
Location variables		
Rural	Dummy	Household lives in rural area. Yes = 1, No = 0
Savannah dummy (savannah = 1, 0 otherwise)	Dummy	Household lives in the Savannah parts of Ghana. Yes = 1, No = 0
Forest dummy (forest =1, 0 otherwise)	Dummy	Household lives in the Forest parts of Ghana. Yes = 1, No = 0
Coastal dummy (coastal =1, 0 otherwise)	Dummy	Household lives in the Coastal parts of Ghana. Yes = 1, No = 0
Accra dummy (Accra =1, 0 otherwise)	Dummy	Household lives in Accra. Yes = 1, No = 0

Table A2
Summary statistics (mean values) of variables for subsamples

	GLSS 7				GLSS 6				Pooled dataset			
	Female	Male	Rural	Urban	Female	Male	Rural	Urban	Female	Male	Rural	Urban
Clean cooking fuel (LPG)	0.015	0.014	0.006	0.024	0.014	0.013	0.005	0.024	0.015	0.013	0.006	0.024
kerosene, firewood, charcoal, and other fuels	0.114	0.087	0.101	0.087	0.127	0.084	0.086	0.109	0.121	0.085	0.093	0.099
Financial inclusion – FI (1)	0.215	0.256	0.196	0.307	0.199	0.249	0.149	0.345	0.206	0.252	0.171	0.328
Financial inclusion – FI (2)	0.502	0.595	0.456	0.716	0.404	0.505	0.344	0.646	0.451	0.545	0.396	0.677
Financial inclusion – FI (3)	0.513	0.599	0.464	0.721	0.416	0.510	0.352	0.652	0.462	0.550	0.403	0.683
Total household income per capita (in natural log)	7.504	7.645	7.114	8.267	7.134	7.387	7.016	7.698	7.311	7.501	7.061	7.950
Gender (Female = 1, Male = 0)	–	–	0.280	0.353	–	–	0.238	0.339	–	–	0.257	0.345
Household head is employed (Yes = 1, No = 0)	0.749	0.831	0.796	0.819	0.837	0.921	0.914	0.875	0.795	0.881	0.860	0.850
Size of household	3.412	4.606	4.704	3.594	3.359	4.658	4.766	3.686	3.384	4.635	4.737	3.645
Size of household squared	16.291	30.696	31.845	18.528	15.554	30.366	31.644	19.224	15.905	30.511	31.736	18.917
Age of household head	49.580	44.922	47.454	44.890	49.248	44.675	47.477	44.033	49.406	44.784	47.467	44.412
Number of male household members under 5	0.188	0.326	0.334	0.214	0.186	0.338	0.350	0.225	0.187	0.333	0.343	0.220
Number of female household members under 5	0.184	0.306	0.305	0.217	0.165	0.325	0.333	0.212	0.174	0.317	0.320	0.214
Number of household members within 15–24 age range	0.797	0.852	0.914	0.727	0.791	0.845	0.893	0.749	0.794	0.848	0.902	0.740
Household members over 64 years	0.276	0.229	0.291	0.180	0.263	0.207	0.273	0.160	0.270	0.217	0.281	0.168
Literacy status of household head (Yes = 1, No = 0)	0.650	0.735	0.603	0.853	0.614	0.709	0.573	0.821	0.631	0.721	0.587	0.835
Married	0.210	0.710	0.595	0.499	0.231	0.733	0.639	0.531	0.221	0.723	0.618	0.517
Consensual union	0.072	0.098	0.094	0.083	0.054	0.099	0.095	0.075	0.062	0.098	0.095	0.078
Separated	0.091	0.022	0.039	0.048	0.092	0.018	0.031	0.048	0.091	0.020	0.035	0.048
Divorced	0.136	0.028	0.057	0.068	0.168	0.028	0.055	0.083	0.153	0.028	0.056	0.076
Widowed	0.368	0.022	0.138	0.117	0.352	0.022	0.120	0.109	0.360	0.022	0.128	0.113
Never married	0.123	0.122	0.077	0.184	0.103	0.101	0.059	0.155	0.113	0.110	0.068	0.168
Rural dummy (rural = 1, 0 otherwise)	0.520	0.603	–	–	0.473	0.595	–	–	0.495	0.599	–	–
Nationality (Ghanaian = 1, 0 otherwise)	0.991	0.986	0.988	0.986	0.986	0.987	0.989	0.983	0.989	0.986	0.989	0.985
Savannah dummy (savannah = 1, 0 otherwise)	0.261	0.403	0.475	0.199	0.234	0.390	0.463	0.197	0.247	0.396	0.469	0.198
Forest dummy (forest =1, 0 otherwise)	0.442	0.376	0.382	0.417	0.471	0.396	0.414	0.422	0.457	0.387	0.399	0.420
Coastal dummy (coastal =1, 0 otherwise)	0.250	0.181	0.143	0.283	0.187	0.117	0.123	0.155	0.217	0.145	0.132	0.212
Accra dummy (Accra =1, 0 otherwise)	0.047	0.040	0.000	0.100	0.108	0.096	0.000	0.226	0.079	0.072	0.000	0.171
Distance to nearest financial institution (in kilometers)	10.973	12.801	13.354	10.702	13.518	15.882	16.829	13.154	12.306	14.521	15.234	12.070
Observations	4236	9387	7865	5758	4661	11,870	9271	7260	8897	21,257	17,136	13,018

Note: FI(1) - FI(3) are the three measures of financial inclusion.

Table A3
Probit regression – robustness checks

	GLSS 7		GLSS 6		Pooled	
	FI (2)	FI (3)	FI (2)	FI (3)	FI (2)	FI (3)
Distance to nearest financial institution (in kilometers)	−0.0312***	−0.0311***	−0.0135***	−0.0132***	−0.0223***	−0.0221***
Total household income per capita (in natural log)	0.2424***	0.2426***	0.2782***	0.2835***	0.2578***	0.2605***
Gender (Female = 1, Male = 0)	−0.0705**	−0.0520	−0.0780**	−0.0550*	−0.0758***	−0.0552**
Household head is employed (Yes = 1, No = 0)	0.0403	0.0495	−0.0996**	−0.0908**	−0.0266	−0.0184
Size of household	0.1473***	0.1518***	0.1360***	0.1436***	0.1412***	0.1472***
Size of household squared	−0.0044***	−0.0047***	−0.0049***	−0.0052***	−0.0046***	−0.0049***
Age of household head	−0.0039***	−0.0036***	−0.0020*	−0.0019*	−0.0031***	−0.0029***
Number of male household members under 5	−0.1198***	−0.1184***	−0.0741***	−0.0827***	−0.0978***	−0.1017***
Number of female household members under 5	−0.0922***	−0.0928***	−0.0816***	−0.0815***	−0.0901***	−0.0903***
Number of household members within 15–24 age range	0.0231	0.0263*	0.0542***	0.0527***	0.0401***	0.0406***
Household members over 64 years	0.0021	−0.0049	0.0164	0.0067	0.0143	0.0059
Literacy status of household head (Yes = 1, No = 0)	0.5115***	0.5095***	0.6430***	0.6347***	0.5825***	0.5773***

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Table A3 (*continued*)

	GLSS 7		GLSS 6		Pooled	
	FI (2)	FI (3)	FI (2)	FI (3)	FI (2)	FI (3)
Household head's marital status (base category = married)						
Consensual union	−0.3126***	−0.3031***	−0.1649***	−0.1526***	−0.2332***	−0.2226***
Separated	−0.1853***	−0.1687***	−0.2048***	−0.1931***	−0.1916***	−0.1772***
Divorced	−0.2558***	−0.2261***	−0.3325***	−0.3287***	−0.2973***	−0.2823***
Widowed	−0.1772***	−0.1818***	−0.1947***	−0.1832***	−0.1773***	−0.1743***
Never married	−0.0644	−0.0497	0.0826*	0.0779*	0.0041	0.0086
Rural dummy (rural = 1, 0 otherwise)	−0.4222***	−0.4113***	−0.5510***	−0.5481***	−0.4885***	−0.4816***
Nationality (Ghanaian = 1, 0 otherwise)	0.3868***	0.4025***	0.1811**	0.1869**	0.2559***	0.2664***
Savannah dummy (savannah = 1, 0 otherwise)	0.1588**	0.1501**	−0.1209**	−0.1182**	−0.0236	−0.0239
Forest dummy (forest =1, 0 otherwise)	−0.0730	−0.0730	−0.1290***	−0.1144***	−0.1554***	−0.1446***
Coastal dummy (coastal =1, 0 otherwise)	−0.0589	−0.0561	−0.3409***	−0.3164***	−0.2452***	−0.2294***
Year	–	–	–	–	0.1535***	0.1502***
Constant	−1.9935***	−2.0400***	−2.2722***	−2.3444***	−2.1052***	−2.1651***
Observations	13,623		16,531		30,154	

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. FI(2) and FI(3) are the two measures of financial inclusion for robustness checks.

Table A4
Effect of financial inclusion on household cooking fuels in Ghana – robustness checks

	LPG cooking fuel			Kerosene, firewood charcoal and other fuel		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
Financial inclusion – FI (2)	0.0259***	0.0233***	0.0272***	−0.2477***	−0.1139***	−0.1756***
Total household income per capita (in natural log)	−0.0021**	−0.0004	−0.0015***	0.0310***	0.0126***	0.0187***
Gender (Female = 1, Male = 0)	−0.0040*	−2.02e-05	−0.0019	0.0765***	0.0394***	0.0518***
Household head is employed (Yes = 1, No = 0)	0.0023	−0.0021	−0.0008	−0.0183	−0.0033	−0.0269***
Size of household	−0.0008	−0.0023	−0.0014*	0.0163*	−0.0045	0.0008
Size of household squared	0.0001	0.0002	0.0001**	−0.0006	0.0004	0.0001
Age of household head	0.0002**	2.61e-05	0.0001**	−0.0004	−0.0002	−0.0004**
Number of male household members under 5	0.0011	−0.0024**	−0.0009	−0.0046	−0.0015	−0.0018
Number of female household members under 5	−0.0014	−0.0005	−0.0012	−0.0083	0.0096*	0.0057
Number of household members within 15–24 age range	0.0003	0.0003	−2.96e-05	0.0144**	−0.0032	0.0030
Household members over 64 years	−0.0014	0.0002	−0.0006	−0.0072	−0.0079	−0.0048
Literacy status of household head (Yes = 1, No = 0)	−0.0025	−0.0003	−0.0011	0.0609***	0.0413***	0.0516***
Household head's marital status (base category = married)						
Consensual union	0.0013	0.0047**	0.0036*	−0.0349**	0.0234*	0.0039
Separated	0.0103**	0.0001	0.0039	0.0081	−0.0154	−0.0066
Divorced	−0.0026	0.0018	−3.75e-05	0.0211	−0.0228	−0.0093
Widowed	0.0046*	0.0008	0.0025*	−0.0117	−0.0048	−0.0102
Never married	0.0083**	0.0100**	0.0100***	−0.0467**	−0.0346**	−0.0366***
Rural dummy (rural = 1, 0 otherwise)	0.0035	0.0057***	0.0034**	−0.0457***	−0.0809***	−0.0824***
Nationality (Ghanaian = 1, 0 otherwise)	−0.0038	0.0005	−0.0002	0.0458*	−0.0330	−0.0104
Savannah dummy (savannah = 1, 0 otherwise)	−0.0378**	−0.0154**	−0.0188***	−0.0200	0.0086	0.0068
Forest dummy (forest =1, 0 otherwise)	−0.0406**	−0.0201***	−0.0226***	−0.0811	0.0414**	0.0080
Coastal dummy (coastal =1, 0 otherwise)	−0.0379**	−0.0184***	−0.0181***	0.0044	0.1815***	0.1237***
Year	–	–	−0.0028***	–	–	0.0079***
Constant	0.0441**	0.0182*	0.0258***	−0.0562	0.0908**	0.0739**
Observations	13,623	16,531	30,154	13,623	16,531	30,154

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. F(2) is a measure of financial inclusion for robustness check. Additional regressors of the form $(X_i - \mu_X)\widehat{F}_i$ were included to measure heterogenous impacts of FI but not reported.

Table A5
Effect of financial inclusion on household cooking fuels in Ghana – robustness checks

	LPG cooking fuel			Kerosene, firewood charcoal and other fuel		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
Financial inclusion – FI (3)	0.0258***	0.0219***	0.0266***	−0.2464***	−0.1039***	−0.1711***
Total household income per capita (in natural log)	−0.0022**	−0.0004	−0.0015***	0.0309***	0.0118***	0.0186***
Gender (Female = 1, Male = 0)	−0.0044*	0.0002	−0.0020	0.0754***	0.0396***	0.0517***
Household head is employed (Yes = 1, No = 0)	0.0026	−0.0020	−0.0007	−0.0175	−0.0026	−0.0269***
Size of household	−0.0008	−0.0023	−0.0013*	0.0160*	−0.0061	3.09e-05
Size of household squared	0.0001	0.0002	0.0001**	−0.0006	0.0005	0.0002
Age of household head	0.0002**	2.71e-05	0.0001**	−0.0004	−0.0002	−0.0005**
Number of male household members under 5	0.0009	−0.0024**	−0.0010	−0.0051	−0.0010	−0.0020
Number of female household members under 5	−0.0012	−0.0006	−0.0012	−0.0089	0.0099*	0.0056
Number of household members within 15–24 age range	0.0005	0.0004	0.0001	0.0144**	−0.0035	0.0030
Household members over 64 years	−0.0015	0.0001	−0.0007	−0.0075	−0.0077	−0.0050
Literacy status of household head (Yes = 1, No = 0)	−0.0026	4.85e-05	−0.0012	0.0623***	0.0398***	0.0508***

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Table A5 (*continued*)

	LPG cooking fuel			Kerosene, firewood charcoal and other fuel		
	GLSS 7	GLSS 6	Pooled	GLSS 7	GLSS 6	Pooled
Household head's marrital status (base category = married)						
Consensual union	0.0018	0.0048**	0.0038**	−0.0364**	0.0241*	0.0036
Separated	0.0109**	0.0005	0.0044*	0.0064	−0.0177	−0.0090
Divorced	−0.0018	0.0021	0.0005	0.0187	−0.0256*	−0.0123
Widowed	0.0050*	0.0008	0.0027*	−0.0110	−0.0053	−0.0104
Never married	0.0081**	0.0095*	0.0098***	−0.0464**	−0.0368**	−0.0381***
Rural dummy (rural = 1, 0 otherwise)	0.0036	0.0059***	0.0035**	−0.0472***	−0.0810***	−0.0835***
Nationality (Ghanaian = 1, 0 otherwise)	−0.0038	0.0008	−0.0003	0.0483*	−0.0364	−0.0104
Savannah dummy (savannah = 1, 0 otherwise)	−0.0380**	−0.0158**	−0.0194***	−0.0078	0.0106	0.0115
Forest dummy (forest =1, 0 otherwise)	−0.0409**	−0.0204***	−0.0232***	−0.0680	0.0437***	0.0134
Coastal dummy (coastal =1, 0 otherwise)	−0.0383**	−0.0189***	−0.0189***	0.0178	0.1855***	0.1309***
Year	–	–	−0.0026***	–	–	0.0072***
Constant	0.0443**	0.0177*	0.0256***	−0.0679	0.0986**	0.0737**
Observations	13,623	16,531	30,154	13,623	16,531	30,154

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Estimations carried out with robust standard errors. F(3) is a measure of financial inclusion for robustness check. Additional regressors of the form $(X_i - \mu_X)\widehat{F}_i$ were included to measure heterogenous impacts of FI but not reported.

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