CLEAN ENERGY TRANSITION IN WEST AFRICA: DOES SOCIAL CAPITAL HAVE A ROLE TO PLAY?

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1. Introduction

In most Sub-Saharan African countries, many households in both rural and urban areas rely heavily on traditional biomass fuels for cooking (IRENA, 2024; Byaro et al., 2024; Khavari et al., 2023; Murshed, 2022; Dagnachew et al., 2020). Recent evidence suggests that indoor air pollution from biomass cookstoves is associated with significant health risks (Byaro et al., 2024; Martey et al., 2024; Dherani et al., 2022; Kyayesimira and Florence, 2021; De la Sota et al., 2018). As health is an important component of human capital, the long-term implications for economic growth and development are potentially significant. Over the past two decades, local governments and international development partners in Sub-Saharan Africa have invested significant resources to increase the uptake of clean energy, particularly among the poor. The rationale behind these interventions, which aim to reduce energy poverty, is that access to clean and reliable energy is a

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key step towards achieving the 2030 Sustainable Development Goals (SDGs) (IRENA, 2024; Okere et al., 2023; Kwakwa, 2023; Murshed, 2022; Mungai et al., 2022; Garba and Bellingham, 2021; Chirambo, 2018). There is an ongoing debate among economists about what factors really drive the adoption of clean energy such as LPG in developing countries.

This paper examines the impact of households' social capital on their likelihood of adopting the modern cooking technology, LPG. The need to be socially connected is an important dimension of economic behavior. This is particularly true in most developing countries, where market failures prevent people from accessing valuable economic assets that are central to their well-being. These assets include not only equipment or physical assets, but also information, skills, techniques, or innovations. An important dimension of the optimization behavior of rational economic agents is to invest part of their time endowment in social relationships with those who can facilitate access to these assets. This is referred to as investment in social capital because it is mediated through social interactions rather than directly through competitive markets (Claridge, 2020a, 2020b; Claridge, 2018; Nooteboom, 2007; Schuller, 2007). While there is relative consensus on the economic benefits of social capital, the main challenge is which definition to use. Putnam (1993) defines social capital as features of social organization, such as trust, norms, and networks that can improve the efficiency of society. Social capital can also be defined as the institutions, relationships, attitudes, and values that govern interactions between people (Claridge, 2020c). Claridge (2020c) identified no less than 112 definitions of social capital, covering three main dimensions: structural, which refers to the structure and configuration of social relationships and association membership (bonding ties, bridging ties, linking ties); relational, which refers to the characteristics and qualities of social relationships (trust, norms of trustworthiness and sanctioning commitment); and cognitive, which refers to how interactions with networks and associations are coded. Social capital then overlaps in many dimensions: generalized trust, social norms, social networks, and civic and collective action.

Following Durante et al. (2024) and Van Staveren and Knorringa (2007), this paper adopts the structural dimension of social capital: household social capital captures the extent to which households are involved in local collective and civic action through their participation in various local associations. The main question addressed in this paper is: to what extent do remittances help households to build their social capital? An extensive literature has documented important potential benefits associated with social capital. It can be associated with greater resilience to negative shocks to well-being (Akakpo et al., 2024), lower risk of food insecurity (Egamberdiev, 2024), higher agricultural investment (Khadjavi et al., 2021), or business productivity (Nguyen, 2022; Walther et al, 2019).

The main questions addressed in this paper are: How does social capital affect household preferences for LPG cooking technology? What are the potential mechanisms through which these effects operate? To answer these questions, we draw on original databases from seven countries in the West African Economic and Monetary Union (WAEMU), which provide detailed information on households' social connections through their participation in various community associations. Specifically, we compare the likelihood of adopting LPG cooking technology between socially connected households and households that do not participate in local activities involving groups of households with a common goal. Econometrically, this is potentially challenging as social capital may not be randomly distributed across households: households choose to become members of local associations and ignoring this can lead to selection bias.

We address this challenge using three complementary comprehensive identification strategies: selection-on-observables, entropy balancing (EB), and the augmented inverse propensity weighted (AIPW) estimator. We find that social capital is associated with a greater likelihood of adopting LPG cooking technology. Regarding the possible mechanisms behind this positive effect, the results suggest that social capital not only increases the likelihood of households' financial inclusion, but also their savings. These findings are particularly policy relevant in the WAEMU, where energy poverty is significant and financial inclusion remains extremely low. They will help policymakers understand the key role of social capital in driving the transition from traditional biomass cooking fuels to clean cooking energy, and the underlying mechanisms; and then design relevant interventions for clean energy access. The implications of these findings suggest that interventions aimed at promoting local collective action and social trust may help to increase the uptake of clean energy cookstoves.

This paper brings together three strands of literature. First, it contributes to the literature on the determinants of household decisions to adopt clean energy technologies. Recent studies by Fentie et al. (2023), Wassie et al. (2021) and Alem and Demeke (2020) for Ethiopia, Gelo et al. (2023) for South Africa, Gill-Wiehl et al. (2022) for India, Jaime et al. (2020) for Chile, and Adusah-Poku and Takeuchi (2019) and Karimu et al. (2016) for Ghana have documented the central role of household income. Other key determinants include risk aversion (Frempong et al., 2024; Adjei-Mantey and Takeuchi, 2023), social networks (Li et al., 2024), participation in non-farm businesses (Ma et al., 2024; Zheng, 2023), gender (Totouom, 2024; Adusah-Poku et al., 2023), and financial inclusion (Addai et al., 2022; Hsu et al., 2021; Twumasi et al., 2020). At the macroeconomic level, Kwakwa (2023) documents the key role of institutional quality, trade openness, and financial development in promoting access to clean fuels in Africa. Second, this paper relates to the recently growing literature on the welfare implications of clean energy adoption. Su and Azam (2023) found that LPG adoption affects intra-household time allocation and leads to a reduction in women's domestic workload in India. Mamidi et al. (2021) found that clean energy transition is associated with higher UNDP Human Development Index of households in India. Frempong et al. (2021)

showed that the introduction of cooking gas improved children's learning outcomes in rural Ghana. Finally, this paper relates to the literature on the economic effects of social capital. Recent evidence from Akakpo et al. (2024) for Togo suggests that social capital improves household resilience to shocks and household welfare. Egamberdiev (2024) finds that social capital acts as a coping mechanism for food insecurity in Kyrgyzstan. Social capital is associated with greater financial inclusion (Heikkilä et al., 2016; Dufhues et al., 2011). Social capital improves agricultural investments (Khadjavi et al., 2021) and the productivity of firms (Nguyen, 2022; Kolstad and Wiig, 2013; Barr, 2002; Fafchamps and Minten, 2002; Fafchamps and Minten, 2001).

Our contribution to this previous related literature is twofold. First, instead of focusing on purely economic factors, this article examines the impact of social capital on household preferences for LPG technology, the most widely used environmentally friendly cooking method in West Africa. The relevance of examining the impact of social capital in WAEMU countries lies in the absence of well-functioning market institutions, which force households to rely heavily on informal social arrangements for many of their economic decisions. Second, our paper considers a multi-country context, which increases the likelihood of external validity of the results.

The remainder of the paper is structured as follows: Section 2 outlines the background. Section 3 outlines the research design, which describes the data used in the paper and provides important summary statistics for the variables used in the regressions, and presents the empirical framework. Section 4 discusses the results. Section 5 concludes and discusses the policy implications.

2. *Background*

Economics: In this section, we present a simple conceptual framework to help think about the potential effects of social capital on households' decisions to adopt LPG technology for cooking. Social capital can have direct and indirect effects (i.e., spillovers) on household preferences for LPG cooking technology. Direct effects correspond to changes in the probability of adopting LPG technology for cooking as a result of changes in incentives induced by repeated contacts with others. In contrast, indirect effects arise from changes in the probability of adopting LPG technology for cooking as a result of changes in the economic situation induced by investments in social capital. For the direct effects of social capital, two mechanisms may operate: risk aversion and peer effects. LPG is a risky technology as it may involve a non-negligible risk of explosion and thus injury. The adoption rate may therefore be low among risk-averse households (Frempong et al., 2024; Adjei-Mantey and Takeuchi, 2023). Investing in social capital can help risk-averse households reduce their risk aversion by learning about the risks associated with LGP technology through social networks (Li et al., 2024). For the indirect effects, we focus on the impact of social capital on financial inclusion (Heikkilä et al., 2016; Dufhues et al., 2011), which in turn relax households' financial constraints and promotes the adoption of LPG technology (Addai et al., 2022; Hsu et al., 2021; Twumasi et al., 2020).

Institutional: This section briefly presents some stylized facts about energy production and consumption in the WAEMU countries. The West African Economic and Monetary Union (WEAMU) has eight members: Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo, with an area of 3500000 km^2 and a population estimated at over 120 million in 2017. In the WEAMU region, primary energy production is dominated by biomass energy. In 2018, oil and natural gas accounted for 9% and 6% respectively of total primary energy production in the UEMOA region. 67% of the region's oil production comes from Côte d'Ivoire and 33% from Niger. Côte d'Ivoire is the main producer of natural gas (97.7% of the region's production). Niger and Senegal are the other two gas producers in the region: Niger accounts for 1.8% of UEMOA gas production and Senegal for 0.5% (IFDD, 2020). In December 2001, the WAEMU adopted a common energy policy (PEC) with the following objectives: i) to ensure the Union's security of energy supply; ii) to develop and ensure the optimal management of energy resources through the systematic interconnection of electricity networks and the construction of common facilities; iii) to promote renewable energy and energy efficiency; iv) to develop and improve access to energy services for the Union's rural population; v) to contribute to the preservation of the environment (ADUA, 2019). The WAEMU countries are also part of the West African Power Pool (WAPP) initiative, set up in 1999 to ensure a regular, reliable and affordable supply of electricity.

3. Research Design

3.1. The Data Source: The empirical analysis is based on the 2021/2022 round of the Enquête Harmonisée sur le Conditions de Vie des Ménages (EHCVM) for Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Niger, Senegal and Togo, with data collected in 2021 and 2022. Mali is not included because the survey section on social capital was not available for the Malian data. We also consider only the 2021/2022 round, rather than both the 2018/2019 and 2021/2022 rounds, because the survey section on social capital was introduced for the 2021/2022 round. These surveys are representative of the national, regional, and urban/rural levels. The main objective of the EHCVM is to provide reliable data on various household welfare indicators to enable analysis to inform public policies. The survey methodology is harmonized within the same framework in all seven countries. The surveys are conducted in two waves to take account of the seasonality of household consumption.

The survey design for the 2021/2022 round was based on that of the 2018/2019 round.

The 2018/2019 sample was drawn using a two-stage stratified sampling plan. The stratum is the combination of district and area of residence. Within each stratum, in the first stage, clusters (primary sampling units) were selected with probability proportional to their size in terms of number of households. In the second stage, 12 households were selected with equal probability within each cluster. For the 2021/2022 survey, the strategy was to revisit the same clusters. This involved either interviewing the 12 households from the 2018/2019 survey if found (after the enumeration stage), or interviewing the households found and completing the sample to 12 in clusters where fewer than 12 households were found during the enumeration stage. Table 1 displays the distribution of samples across countries.

3.2. Variables and Descriptive Evidence: *Outcome variable:* The main outcome variable is derived from data section 11, which provides detailed information on the characteristics of the dwelling, in particular, the different energies used for cooking. Households were asked to indicate whether LPG was the main fuel used for cooking in the household. We then code the outcome variable (*LPGAdoption*) as a dummy variable equal to one for households who adopted LPG as their main cooking technology, and equal to zero otherwise.

Potential mechanism variables: Potential mechanisms are dummy variables for whether households are financially included or not. Household financial inclusion refers to the financial inclusion of the household head. Four dummy variables are then considered. *BankAccount*, which equals to one if the household head has an account in a traditional bank, and zero otherwise; *Microfinance*, which equals one if the household head has an account with a microfinance institution and zero otherwise; *MobileBanking*, which equals one if the household head use mobile banking services and zero otherwise It is important to note that mobile banking is very different from mobile money. Mobile banking provides access to an existing bank account via a mobile phone. It allows owners to access their savings anytime, anywhere (Suri, 2017); *Roscas*, which equals one if the household head is a member

Table 1
SAMPLE DISTRIBUTION ACROSS COUNTRIES

Countries	Freq.	Percent	Cum.
Benin	7893	15.68	15.68
Burkina Faso	6586	13.08	28.77
Cote d'Ivoire	12737	25.31	54.07
Guinea-Bissau	4231	8.41	62.48
Niger	6553	13.02	75.50
Senegal	6072	12.06	87.56
Togo	6261	12.44	100.00
Total	50333	100.00	

of a rotating saving and credit association and zero otherwise. We also introduce *Savings*, which is a dummy variable equal to one if financially included households actually save through these different savings instruments and zero otherwise.

Treatment variable: The treatment variable is derived from data section 20b. As in Durante et al. (2024) and Van Staveren and Knorringa (2007), we consider collective action through participation in local associations as one of the main mechanisms through which households build their social capital. Six types of local associations are considered: (i) local associations, (ii) religious associations, (iii) professional associations, (iv) family associations, (v) savings associations, and (vi) political parties. As households may participate in more than one of these associations, our treatment variable (*SocialCapital*) is coded as a dummy variable that equals one if a household participates in these associations and zero otherwise.

Control variables: The likelihood of adopting LPG technology for cooking cannot be explained by household social capital alone. In this section, we present relevant covariates. The first two covariates we introduce are *Wood* and *Charcoal*, which are dummy variables equal to one for households that mainly rely on wood (purchased or collected) and charcoal as their main cooking fuels, and zero otherwise. They will help to test the potential complementarity or substitutability between LPG and traditional biomass fuels for cooking. As recently documented in Wassie et al. (2021) for Ethiopia, the choice of cooking fuel is linked to the distance to the wood source.

The selection of the other main covariates is based on the most relevant literature cited above. The main household level covariates included are household size, age, gender, disability, education, marital status, and religion of the household head. We therefore code *Female*, which is a dummy equal to one if the household is headed by a woman and zero otherwise; and define *Hsize* and *Age*, which are the size of the household, the FAO number of adult equivalents, and the age of the household head in years, respectively. For the educational level of the head of the household, we define three dummy variables, *Primary*, *Secondary*, and *University*, equal to one for primary, secondary, and university, respectively, and zero otherwise. The reference educational level is "No education," The marital status of the household head is defined by five dummy variables, *Monogamous*, *Polygamous*, *CommonLaw*, *Widowed*, and *Divorced*, which take the value one for household heads in monogamous, polygamous, cohabiting, widowed, and divorced unions and zero otherwise. The reference marital status is single. The religion of the household head is defined by three dummy variables, *Muslim*, *Christian*, and *Traditionalist*, equal to one for Muslim, Christian, and Animist household heads, respectively, and zero otherwise. The reference religion is "no religion" or "other." *MajorDisability* is a dummy variable equal to one if the head of the household has a major disability and zero otherwise.

The list of household level covariates is completed by village or community level variables. The first variable we include is the distance to the nearest town

(*Distance*). For rural households, this distance is generally taken as a proxy for access to agricultural markets, and then as an important determinant of rural household income. Other variables include *AsphaltRoad* (dummy variable equal to one if the main road connecting the community with neighboring communities is asphalted, and equal to zero otherwise), *Electricity* (dummy variable equal to one if the community has access to reliable electricity, and equal to zero otherwise), *Water* (dummy variable equal to one if the community has access to potable and safe water, and equal to zero otherwise), and *Topology* (dummy variable equal to one if the community is located on a hill, and equal to zero otherwise). Table 2 presents descriptive statistics of these variables.

The main idea behind the testing strategy is that of non-random self-selection into local associations. This means that we cannot a priori distinguish households

Table 2
DESCRIPTIVE STATISTICS OF THE MAIN VARIABLES

Variables	Observations	Means	Std. Dev
LPGAdoption	50331	0.222	0.415
BankAccount	49395	0.129	0.336
Microfinance	49395	0.077	0.267
MobileBanking	49395	0.424	0.494
Roscas	46992	0.140	0.347
Savings	25766	0.446	0.497
SocialCapital	50333	0.396	0.489
Wood	50333	0.733	0.442
Charcoal	50331	0.369	0.482
Age	50333	47.14	13.76
Female	50333	0.199	0.399
Hsize	50333	4.470	2.819
MajorDisability	50333	0.061	0.240
Primary	50332	0.181	0.385
Secondary	50332	0.186	0.389
University	50332	0.052	0.223
Monogamous	50333	0.577	0.493
Polygamous	50333	0.174	0.379
CommonLaw	50333	0.025	0.158
Widowed	50333	0.110	0.313
Divorced	50333	0.037	0.189
Muslim	50333	0.538	0.498
Christian	50333	0.321	0.467
Traditionalist	50333	0.095	0.294
Distance	50297	14.98	20.41
AsphaltRoad	50321	0.405	0.490
Electricity	50321	0.618	0.485
Water	50321	0.512	0.499
Topology	50309	0.460	0.498

that are more socially connected from those that are not, and thus the difference in the likelihood of adopting LPG induced by social capital. Table 3 shows the results of balance tests between the subsample of households with social capital and the subsample of households without social capital. These results suggest that the two groups of households are distinctly different. More importantly, and without implying a causal relationship, the results suggest that socially connected households are more likely to adopt LPG technology for cooking and more likely to be financially integrated.

3.3. Empirical Framework: *Baseline specification:* Our empirical framework follows the traditional literature on the decision to adopt a modern risky

Table 3
BALANCE TESTS

	SocialCapital=1	**SocialCapital=0**	**Difference**
Variables	**Mean (1)**	**Mean (0)**	**Mean (1)-Mean (0)**
LPGAdoption	0.234	0.214	***(+)
BankAccount	0.163	0.107	***(+)
Microfinance	0.116	0.052	***(+)
MobileBanking	0.447	0.409	***(+)
Roscas	0.235	0.080	***(+)
Savings	0.476	0.423	***(+)
Wood	0.716	0.744	***(−)
Charcoal	0.433	0.327	***(+)
Age	47.77	46.73	***(+)
Female	0.193	0.204	***(−)
Hsize	4.752	4.284	***(+)
MajorDisability	0.057	0.064	***(−)
Primary	0.196	0.171	***(+)
Secondary	0.224	0.161	***(+)
University	0.068	0.042	***(+)
Monogamous	0.579	0.576	n.s
Polygamous	0.192	0.163	***(+)
CommonLaw	0.022	0.027	***(−)
Widowed	0.107	0.111	n.s
Divorced	0.038	0.036	n.s
Muslim	0.486	0.573	***(−)
Christian	0.361	0.295	***(+)
Traditionalist	0.115	0.082	***(+)
Distance	13.71	15.82	***(−)
AsphaltRoad	0.422	0.393	***(+)
Electricity	0.621	0.616	n.s
Water	0.517	0.509	**(+)
Topology	0.414	0.491	***(−)

Notes: ***(statistically significant at 1%); **(statistically significant at 5%); *(statistically significant at 10%); n.s (not statistically significant).

technology, where the adoption decision is a cost-benefit trade-off. In such a framework, a rational economic agent adopts if the expected net benefit is positive (Foster and Rosenzweig, 2010; Besley and Case, 1993). Hence, let $LPG_{hvc} \in \{0, 1\}$ be a variable that equals one if household h in village v in country c has adopted LGP for cooking, and zero otherwise. Now suppose that a household makes the investment in this modern cooking technology if the expected household utility, U^*_{hvc}, from doing so is positive. That is:

$$LPG_{hvc} = \begin{cases} 1 & if \quad U^*_{hvc} > 0 \\ 0 & if \quad U^*_{hvc} \leq 0 \end{cases} \tag{1}$$

Throughout the analysis, a linear probability (LPM) specification is used for the discrete choice model in (1). As suggested by Bandiera and Rasul (2006), the LPM specification outperforms the traditional nonlinear discrete models, probit and logit, in the presence of fixed effects. It also allows the estimated coefficients to be interpreted as marginal effects. However, we run a probit specification for the robust check. Hence, the key relationship this paper explores is the following:

$$LPG_{hvc} = \alpha + \beta SocialCapital_{hvc} + \Gamma'' X_{hvc} + \Upsilon'' Y_{vc} + \psi_c + \varepsilon_{hvc} \tag{2}$$

where X_{hvc} is the vector of household level covariates and Y_{vc} is the vector of community level covariates. ψ_c are country fixed effects introduced to control for country shocks experienced by all households in the same country. ε_{hvc} is a random error term.

Selection-on-observables: The parameter of interest is β, which captures the direct effect of social capital on the likelihood of adopting LPG technology for cooking. β is identified in regression equation (2) if, conditional on household controls, community level controls, and country fixed effects, household social capital is not correlated with the unobserved variables that directly affect household preferences for LPG technology. That is:

$$Covariance\left(SocialCapital_{hvc}, \varepsilon_{hvc} \mid X_{hvc}, Y_{vc}, \psi_c\right) = 0$$

Given that we have chosen our covariates based on the most relevant literature and that we have accounted for country effects, which capture an important source of heterogeneity across households, the previous identification condition is likely to hold. The intuition behind this condition is that the $(\mathrm{X_{hvc}}, \mathrm{Y_{vc}}, \psi_c)$ provides enough information to ensure that the effect of social capital on the likelihood of adopting LPG technology is not driven by omitted variables.

Entropy Balancing: Although selection-on-observables is attractive in our context, it may not really reduce selection bias. In observational studies, methods based on covariate balance provide alternatives to address potential selection. This paper mainly relies on Entropy Balancing (EB) as proposed by Hainmueller (2012). It works in two stages. The first stage is the weighting or balancing process, where weights are created by matching the two groups. In the second stage, these weights are used in a weighted regression. In our context, the EB algorithm will create a pseudo-population in which the observed covariates are balanced between socially connected and non-socially connected households. The weights, ω_h, which balance the observed covariates are found by minimizing the entropy distance metric between the two groups of households based on the entropy function, $\omega_h log\omega_h$.

Following the framework proposed by Rosenbaum and Rubin (1983), we denote by $\left(LPG_{hvc}(1), LPG_{hvc}(0)\right)$ of potential outcomes ($LPG_{hvc}(1)$: the likelihood of adopting LPG technology by a socially connected household h, and, $LPG_{hvc}(0)$: the likelihood of adopting LPG technology by a non-socially connected household (h). The objective is to recover β as the conditional average treatment effect of social capital given by:

$$CATE\ (z) = E\left[LPG_{hvc}(1) - LPG_{hvc}(0)|Z_{hvc} = z\right]\ :\ Z_{hvc} = \{X_{hvc}, Y_{vc}, \psi_c\} \qquad (3)$$

The Entropy Balancing (EB) algorithm can be considered as generalization of Propensity Score Matching (PSM) and Inverse Probability Weighting (IPW) where instead of using the score, $Prob(LPG_{hvc}(1) \mid Z_{hvc})$, or the inverse of the score, $1/[Prob(LPG_{hvc}(1)|Z_{hvc})]$, as the balancing weights, a more general weighting function, the entropy function $\omega_h log\omega_h$, is used.

Zhao and Percival (2017) showed that the entropy balancing algorithm is doubly robust as it is the case for the augmented inverse probability weighting (AIPW). Another attractive property of the entropy balancing algorithm for our study is that it allows for the consideration of fixed effects within the matching framework. Recent applications of the entropy balancing matching approach include Apeti and Ly (2024) and Apeti et al. (2023), who use it to identify the impact of power outages and the impact of mobile money on firm performance in developing countries, respectively; and Neuenkirch and Neumeier (2016), who used it to identify the impact of U.S. sanctions on poverty in sanctioned countries. The method will be implemented using the Stata package “ebalance” developed by Hainmueller and Xu (2013).

For robustness checks, we will also implement two alternative doubly robust estimation algorithms, Augmented Inverse Propensity Weighted (AIPW) Estimator and Inverse Probability Weighted Regression Adjustment (IPWRA). AIPW and IPWRA are alternative matching approaches to estimate unbiased treatment effects in presence of confounding. In our context, the Inverse-propensity weighting (IPW) algorithm consists in assigning the inverse of probability of being socially connected and the inverse probability of not being socially connected for control households, non-socially connected households (Cattaneo et al., 2013).

4. Results and Discussion

4.1 Baseline Results: The results of estimating regression equation (2) are presented in Table 4. We present the results for the full sample and for the subsamples of urban and rural households. Looking first at the full sample, the results suggest that being socially connected is associated with an

Table 4
SOCIAL CAPITAL AND LPG TECHNOLOGY ADOPTION (OLS)

	Prob (LPGAdoption=1)		
Explained variable	**Whole**	**Urban**	**Rural**
SocialCapital	***0.0299******	***0.0313******	***0.0222******
	(0.0030)	***(0.0054)***	***(0.0030)***
Wood	−0.5403***	−0.5636***	−0.4916***
	(0.0063)	(0.0074)	(0.0148)
Charcoal	−0.1444***	−0.2021***	−0.0618***
	(0.0037)	(0.0055)	(0.0042)
log Age	0.0528***	0.1004***	0.0205***
	(0.0050)	(0.0098)	(0.0050)
Female	0.0552***	0.0768***	0.0383***
	(0.0048)	(0.0080)	(0.0057)
Hsize	0.0017***	0.0039***	0.0008
	(0.0006)	(0.0010)	(0.0006)
MajorDisability	−0.0088	−0.0253***	0.0089
	(0.0060)	(0.0102)	(0.0066)
Primary	0.0562***	0.0706***	0.0371***
	(0.0041)	(0.0070)	(0.0044)
Secondary	0.1137***	0.1491***	0.0680***
	(0.0048)	(0.0072)	(0.0057)
University	0.2704***	0.2902***	0.2575***
	(0.0085)	(0.0097)	(0.0194)
Monogamous	0.0375***	0.0523***	0.0248***
	(0.0067)	(0.0101)	(0.0086)
Polygamous	0.0197***	0.0271**	0.0122
	(0.0074)	(0.0124)	(0.0089)

(continued)

Table 4 (continued)
SOCIAL CAPITAL AND LPG TECHNOLOGY ADOPTION (OLS)

	Prob (LPGAdoption=1)		
Explained variable	**Whole**	**Urban**	**Rural**
CommonLaw	0.0547***	0.0667***	0.0526***
	(0.0109)	(0.0171)	(0.0136)
Widowed	−0.0116	−0.0169	−0.0093
	(0.0083)	(0.0128)	(0.0098)
Divorced	−0.0334***	−0.0491***	−0.0083
	(0.0097)	(0.0152)	(0.0105)
Muslim	0.0311***	0.0547***	0.0177***
	(0.0071)	(0.0163)	(0.0067)
Christian	0.0282***	0.0542***	0.0242***
	(0.0067)	(0.0158)	(0.0064)
Traditionalist	0.0229***	0.0070	0.0053
	(0.0070)	(0.0182)	(0.0060)
Distance	−0.0185***	−0.0128***	−0.0055***
	(0.0018)	(0.0032)	(0.0023)
AsphaltRoad	0.0532***	0.0370***	0.0460***
	(0.0054)	(0.0078)	(0.0069)
Electricity	−0.0015	0.0174	0.0122**
	(0.0053)	(0.0131)	(0.0053)
Water	0.0309***	0.0045	0.0295***
	(0.0053)	(0.0110)	(0.0060)
Topology	−0.0014	0.0022	−0.0085**
	(0.0044)	(0.0072)	(0.0041)
Burkina Faso	0.1676***	0.2885***	0.0686***
	(0.0079)	(0.0125)	(0.0074)
Cote d'Ivoire	0.1647***	0.2546***	0.0977***
	(0.0066)	(0.0111)	(0.0068)
Guinea-Bissau	−0.0920***	−0.2128***	−0.0094*
	(0.0092)	(0.0162)	(0.0053)
Niger	0.0386***	0.0924***	0.0107*
	(0.0072)	(0.0142)	(0.0060)
Senegal	0.1494***	0.2046***	0.0956***
	(0.0089)	(0.0137)	(0.0107)
Togo	−0.0520***	−0.0837***	−0.0303***
	(0.0071)	(0.0138)	(0.0056)
Intercept	0.2683***	0.0500	0.3511***
	(0.0225)	(0.0408)	(0.0264)
Observations	50270	21739	28531
Adj R-squared	51.19%	49.38%	35.07%

Notes: Robust standard errors are in parentheses ***(statistically significant at 1%); **(statistically significant at 5%); *(statistically significant at 10%).

approximately 2.99% higher probability of adopting LPG cooking technology. In urban areas, socially connected households are about 3.13% more likely to adopt LPG cooking technology. In rural areas, the impact of social capital is about 2.22%.

Table 5 shows the results based on the entropy balancing algorithm. The impact of social capital on the probability of adopting the LGP cooking

Table 5
SOCIAL CAPITAL AND LPG TECHNOLOGY ADOPTION (ENTROPY BALANCING)

	Prob (LPGAdoption=1)		
Explained variable	**Whole**	**Urban**	**Rural**
SocialCapital	***0.0281**** ***(0.0028)***	***0.0276**** ***(0.0051)***	***0.0218**** ***(0.0028)***
Wood	−0.5167*** (0.0049)	−0.5395*** (0.0056)	−0.4859*** (0.0114)
Charcoal	−0.1327*** (0.0027)	−0.1921*** (0.0046)	−0.0586*** (0.0028)
log Age	0.0639*** (0.0054)	0.1119*** (0.0106)	0.0274*** (0.0051)
Female	0.0504*** (0.0055)	0.0688*** (0.0089)	0.0360*** (0.0061)
Hsize	0.0006 (0.0006)	0.0024** (0.0011)	0.0004 (0.0006)
MajorDisability	−0.0113* (0.0063)	−0.0294*** (0.0110)	0.0093 (0.0066)
Primary	0.0512*** (0.0038)	0.0633**** (0.0071)	0.0313*** (0.0038)
Secondary	0.1093*** (0.0045)	0.1451*** (0.0071)	0.0624*** (0.0051)
University	0.2678*** (0.0085)	0.2980*** (0.0098)	0.2139*** (0.0186)
Monogamous	0.0301*** (0.0073)	0.0341*** (0.0110)	0.0243*** (0.0089)
Polygamous	0.015* (0.0080)	0.0106 (0.0133)	0.0135 (0.0092)
CommonLaw	0.0473*** (0.0124)	0.0434** (0.0199)	0.0622*** (0.0151)
Widowed	−0.0112 (0.0088)	−0.0224 (0.0139)	−0.0056 (0.0101)

(continued)

Table 5 (continued)
SOCIAL CAPITAL AND LPG TECHNOLOGY ADOPTION (ENTROPY BALANCING)

	Prob (LPGAdoption = 1)		
Explained variable	**Whole**	**Urban**	**Rural**
Divorced	−0.0391***	−0.0654***	−0.0044
	(0.0104)	(0.0160)	(0.0112)
Muslim	0.0191***	0.0430***	0.0149***
	(0.0066)	(0.0161)	(0.0057)
Christian	0.0185***	0.0455***	0.0197***
	(0.0065)	(0.0160)	(0.0057)
Traditionalist	0.0171***	−0.0048	0.0073
	(0.0066)	(0.0180)	(0.0054)
Distance	−0.0163***	−0.0087***	−0.0072***
	(0.0012)	(0.0022)	(0.0017)
AsphaltRoad	0.0478***	0.0334***	0.0397***
	(0.0037)	(0.0057)	(0.0044)
Electricity	−0.0004	0.0049	0.0128***
	(0.0036)	(0.0088)	(0.0037)
Water	0.0193***	0.0011	0.0266***
	(0.0038)	(0.0081)	(0.0042)
Topology	−0.0002	0.0024	−0.0082***
	(0.0030)	(0.0054)	(0.0029)
Burkina Faso	0.1809***	0.3040***	0.0743***
	(0.0052)	(0.0091)	(0.0051)
Cote d'Ivoire	0.1719***	0.2576***	0.1089***
	(0.0049)	(0.0085)	(0.0054)
Guinea-Bissau	−0.0970***	−0.2125***	−0.0115***
	(0.0056)	(0.0120)	(0.0038)
Niger	0.0488***	0.1182***	0.0060
	(0.0056)	(0.0114)	(0.0045)
Senegal	0.1633***	0.2179***	0.0988***
	(0.0061)	(0.0100)	(0.0068)
Togo	−0.0482***	−0.0687***	−0.0298***
	(0.0049)	(0.0104)	(0.0039)
Intercept	0.2271***	0.0310***	0.3310***
	(0.0226)	(0.0425)	(0.0246)
Observations	50270	21739	28531
R-squared	50.45%	48.83%	36.93%

Notes: Standard errors are in parentheses ***(statistically significant at 1%); **(statistically significant at 5%); *(statistically significant at 10%).

technology is now 2.81%, 2.76%, and 2.18% for the full sample and the urban and rural household subsamples, respectively. Several other variables are notable in Table 5. As expected, households that already rely primarily on wood and charcoal as their main cooking fuels are less likely to adopt LPG. More specifically, the use of wood as the main cooking fuel is associated with a 53.95% and 48.59% lower probability of adopting LPG technology for cooking in urban and rural areas, respectively. The use of LPG technology for cooking tends to be more popular among households headed by relatively older people and women, particularly in urban areas. The results in Table 5 suggest that households headed by women are about 6.88% more likely to use LPG technology for cooking.

Household size and severe disability of the household head are most important in urban areas. Urban households with severe disabilities are about 2.94% less likely to adopt LPG technology for cooking. Other key household-level variables that affect households' incentives to adopt LPG technology for cooking include the education, marital status, and religion of household heads. The higher the educational level of the household head, the more likely the household is to adopt LPG cooking technology. The results suggest that the likelihood of adoption is particularly high for households whose head has a higher level of education, especially for urban households. Households whose heads are married in a polygamous or free union are more likely to adopt LPG technology for cooking.

Turning to the effects of community-level covariates, the results suggest that households located further away from towns are less likely to adopt LPG technology for cooking. Accessibility through connection to other neighboring regions via paved roads increases the likelihood of adopting LPG technology for cooking. Access to electricity and the topology of the community play a role in the likelihood of adopting LPG technology for cooking only in rural areas.

We conclude the discussion of the main results with an analysis of country effects. Looking at the full sample, the results suggest that households in Burkina Faso are about 18.09% more likely to adopt LPG technology. This effect is particularly strong for urban households, which are 30.04% more likely to adopt. The results suggest that households in Guinea-Bissau and Togo are less likely to adopt LPG technology for cooking, especially in urban areas. We now turn to the robustness checks.

4.2 Robustness Checks: This section examines the robustness of the baseline results to alternative identification strategies. To this end, we consider two doubly robust matching estimators: the augmented inverse propensity weighted estimator (AIPW) and the inverse probability weighted regression adjustment (IWPRA).

Figure 1 (in Appendix A) shows the common support assumption, which ensures that socially connected and non-socially connected households have a comparable range of covariates. As can be seen, the two estimated densities have most of their respective masses in regions where they overlap, suggesting that the overlap assumption is not violated. In Table 6, we see that the effects of social capital on the likelihood of adopting LPG technology for cooking are consistent with the baseline results.

4.3 Mechanisms: The discussion of the results is complemented by an analysis of the potential mechanisms through which social capital operates. A number of studies have documented the key role of access to finance and savings in shaping household incentives to adopt clean cooking energy technologies (Addai et al., 2022; Hsu et al., 2021; Twumasi et al., 2020). On this basis, we examine the extent to which social capital is associated with greater financial inclusion and then helps households to relax their financial constraints. The results in Table 7 suggest that social capital is not only associated with a higher likelihood of having access to basic savings instruments, but also with a higher likelihood of saving through these instruments. The results suggest that the impact of social capital is particularly important for household participation in ROSCAs. Overall, these findings support the fact that social capital, by promoting household financial inclusion and savings, potentially alleviates financial constraints that hinder households' incentives to adopt LPG technology for cooking.

Table 6
SOCIAL CAPITAL AND LPG TECHNOLOGY ADOPTION (AIWP AND IWPRA)

	Prob (LPGAdoption=1)					
		AIPW			IWPRA	
Explained variable	**Whole**	**Urban**	**Rural**	**Whole**	**Urban**	**Rural**
SocialCapital						
ATE	0.0299***	0.0316***	0.0215***	0.0295***	0.0316***	0.0212****
	(0.0028)	(0.0051)	(0.0029)	(0.0028)	(0.0050)	(0.0029)
ATT				0.0276***	0.0281***	0.0220***
				(0.0028)	(0.0051)	(0.0029)
Observations	50270	21739	28531	50270	21739	28531
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors are in parentheses ***(statistically significant at 1%); **(statistically significant at 5%); *(statistically significant at 10%).

Table 7
SOCIAL CAPITAL AND FINANCIAL INCLUSION (ENTROPY BALANCING)

Explained variable	**Prob BankAccount=1)**	**Prob Microfinance=1**	**Prob MobileBanking=1**	**Prob Roscas=1**	**Prob Savings=1**
SocialCapital	**0.0244*** (0.0031)**	**0.0402*** (0.0028)**	**0.0285*** (0.0041)**	**0.1585*** (0.0035)**	**0.0641*** (0.0064)**
Wood	−0.1314*** (0.0057)	−0.0200*** (0.0047)	−0.070*** (0.0066)	−0.0059 (0.0055)	−0.0854*** (0.0089)
Charcoal	0.0070* (0.0040)	0.0248*** (0.0037)	0.0429*** (0.0053)	0.0218*** (0.0046)	0.0245*** (0.0078)
log Age	0.1018*** (0.0060)	−0.0087* (0.0052)	−0.1095*** (0.0081)	−0.1142*** (0.0065)	0.0255** (0.0131)
Female	−0.0416*** (0.0053)	0.0210*** (0.0054)	−0.0272*** (0.0075)	0.1735*** (0.0074)	−0.0197* (0.0112)
Hsize	0.0049*** (0.0007)	0.0037*** (0.0005)	0.0033*** (0.0008)	0.0008 (0.0006)	0.0047*** (0.0013)
MajorDisability	−0.0174*** (0.0063)	−0.0131** (0.0057)	−0.0659*** (0.0092)	−0.0313*** (0.0068)	−0.0615*** (0.0141)
Primary	0.0320*** (0.0038)	0.0352*** (0.0040)	0.0698*** (0.0057)	0.0301*** (0.0049)	0.0586*** (0.0089)
Secondary	0.1740*** (0.0053)	0.0462*** (0.0044)	0.1003*** (0.0062)	0.0179*** (0.0054)	0.1435*** (0.0092)
University	0.5621*** (0.0103)	0.0244*** (0.0076)	0.1002*** (0.0104)	−0.0170** (0.0082)	0.2866*** (0.0130)
Monogamous	0.0520*** (0.0077)	0.0424*** (0.0059)	0.0448*** (0.0094)	0.0604*** (0.0083)	0.0370*** (0.0138)
Polygamous	0.0521*** (0.0085)	0.0601*** (0.0069)	0.0670*** (0.0108)	0.0789*** (0.0094)	0.0526*** (0.0164)
CommonLaw	0.0253** (0.0128)	0.0419*** (0.0110)	−0.0423*** (0.0167)	0.0437*** (0.0140)	0.0132 (0.0229)
Widowed	0.0187** (0.0087)	0.0147** (0.0077)	−0.0178 (0.0117)	0.0252** (0.0110)	0.0318* (0.0187)
Divorced	0.0186* (0.0102)	0.0249*** (0.0096)	0.0231* (0.0139)	0.0549*** (0.0130)	0.0186 (0.0216)
Muslim	0.0052 (0.0070)	0.0070 (0.0073)	0.0626*** (0.0108)	−0.0496*** (0.0102)	0.0700*** (0.0189)
Christian	0.0257*** (0.0069)	0.0152** (0.0074)	0.0804*** (0.0107)	−0.0345*** (0.0102)	0.0592*** (0.0186)
Traditionalist	−0.0100 (0.0070)	−0.02163*** (0.0081)	0.0236** (0.0118)	0.0093 (0.0112)	0.0477* (0.0218)
Distance	−0.0143*** (0.0013)	−0.0085*** (0.0012)	−0.0191*** (0.0017)	0.0010 (0.0014)	−0.0027 (0.0026)
AsphaltRoad	0.0114*** (0.0039)	−0.0035 (0.0036)	0.0263*** (0.0051)	−0.0115*** (0.0042)	−0.0068 (0.0073)
Electricity	0.0094*** (0.0039)	0.0128*** (0.0040)	0.0087 (0.0060)	0.0077 (0.0051)	0.0266*** (0.0092)

(continued)

Table 7 (continued)
SOCIAL CAPITAL AND FINANCIAL INCLUSION (ENTROPY BALANCING)

Explained variable	Prob BankAccount=1)	Prob Microfinance=1	Prob MobileBanking=1	Prob Roscas=1	Prob Savings=1
Water	0.0102***	0.0004	0.0159***	−0.0086*	−0.0085
	(0.0041)	(0.0040)	(0.0058)	(0.0049)	(0.0088)
Topology	0.0060*	−0.0019	−0.0115***	−0.0064*	−0.0056
	(0.0032)	(0.0030)	(0.0043)	(0.0036)	(0.0068)
Burkina Faso	0.1034***	0.0381***	0.0097	−0.1712***	0.1419***
	(0.0060)	(0.0060)	(0.0084)	(0.0064)	(0.0128)
Cote d'Ivoire	0.0255***	−0.0616***	0.3635***	−0.0482***	0.0494***
	(0.0054)	(0.0045)	(0.0077)	(0.0070)	(0.0117)
Guinea-Bissau	0.0007	−0.0921***	−0.2371***	−0.1703***	0.0584***
	(0.0065)	(0.0045)	(0.0078)	(0.0068)	(0.0193)
Niger	0.0039	−0.0665***	−0.2945***	−0.1576***	0.0903***
	(0.0062)	(0.0053)	(0.0073)	(0.0073)	(0.0263)
Senegal	0.0013	−0.0571***	0.4478***	−0.0923***	−0.1881***
	(0.0066)	(0.0057)	(0.0087)	(0.0072)	(0.0132)
Togo	−0.0113**	0.1721***	0.0892***	−0.1208***	−0.0171
	(0.0055)	(0.0067)	(0.0083)	(0.0070)	(0.0121)
Intercept	−0.3200***	0.0368*	0.6343***	0.5457***	0.1685***
	(0.0245)	(0.0222)	(0.0336)	(0.0277)	(0.0527)
Observations	49333	49333	49333	46938	25728
R-squared	30.14%	11.73%	30.20%	12.02%	11.16%

Notes: Standard errors are in parentheses ***(statistically significant at 1%); **(statistically significant at 5%); *(statistically significant at 10%).

5. *Conclusion*

Understanding households' incentives to adopt clean energy for cooking is critical to the success of clean energy transition policies in Sub-Saharan Africa. While many governments have made important efforts to reduce market barriers to the transition to clean cooking fuels, such as improving infrastructure and information to reduce prices, many households continue to rely primarily on traditional biomass cooking fuels. Sociocultural issues are generally cited as important barriers to household adoption of clean cooking technologies (Schlag and Zuzarte, 2008), suggesting that collective action and community solidarity may play an important role.

In contrast to the existing literature, this paper examines the contribution of social capital to household incentives to adopt LPG cooking technology in seven WAEMU countries, Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Niger, Senegal, and Mali. Household social capital is measured by participation in local associations. Six types of local associations are considered: community associations, religious associations, professional associations, family associations, savings associations, and political parties.

The empirical research is based on the 2021/2022 round of the Enquête Harmonisée sur le Conditions de Vie des Ménages (EHCVM) and uses numerous identification strategies to address potential selection bias related to participation in local associations. We first rely on selection-on-observables and then use various matching algorithms including entropy balancing, augmented inverse propensity weighted estimator, and inverse probability weighted regression adjustment.

We find that socially connected households are more likely to adopt LPG technology for cooking. The intensity of the effect tends to be higher for urban households than for rural households. Building on the most relevant previous literature documenting the key role of access to finance and savings in shaping household preferences for clean cooking energy, we examine the extent to which socially connected households tend to be more financially included. We therefore conclude that financial inclusion is a potential mechanism through which social capital affects households' incentives to adopt LPG cooking technology.

The overall findings provide evidence that social capital can play a key role in promoting the adoption of clean cooking technologies in Sub-Saharan Africa, where most people rely on traditional biomass fuels for cooking. From a policy perspective, the research highlights the need for policy interventions that support local collective action and community solidarity. Specifically, governments should complement purely economic incentives with non-economic measures in the form of proactive local governance that builds social trust and encourages communities to come together around common initiatives.

Despite its strengths and novelty, this study has some limitations that we would like to highlight. Due to data limitations, there is no information on pre-association participation to allow for an after-before comparison. Although we use alternative identification strategies to address selection bias, there is no guarantee that we have successfully mitigated all biases, especially those to unobservable time-varying. While we do not make causal claims, we are confident that our estimates convey a strong correlation between households' incentive to adopt LPG cooking technology and social capital. Our paper provides an important policy option for promoting clean cooking energy in a broader context.

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APPENDIX

Appendix A Figure 1
OVERLAPPING ASSUMPTION